WORKING DRAFT

Regional Toll Revenue Feasibility Study

Prepared for:
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DISCLAIMER

This Report was prepared by Parsons Brinckerhoff (PB), in accordance with an agreement with the Washington State Department of Transportation (WSDOT). This Report is subject to the terms and conditions contained within the consulting agreement, and is meant to be read as a whole and in conjunction with this disclaimer. It is one of several reports dealing with roadway pricing and was developed to support current regional discussions on transportation funding.

The Report, information contained herein, and any statements contained within the Report, are all based upon information provided to PB by, and obtained from, the Washington State Department of Transportation (WSDOT), the Puget Sound Regional Council (PSRC), and other sources. PB makes and provides no assurance as to the accuracy of any such information or any conclusions that are based thereon, and bears no responsibility for the results of any actions taken on the basis of this Report. This report does not constitute a recommendation of the WSDOT or PB.

This Toll Feasibility Study was prepared using the best available information and tools at the time of writing; however, the timing is such that this report does not benefit from work-in-progress refinements to the PSRC model, which when completed, will make the model better suited to toll modeling. In addition, other factors may have changed since the time this report was prepared. Specifications regarding the characteristics of the proposed toll facilities were developed in collaboration with WSDOT, and may or may not represent most likely scenarios for sections with proposed capital improvements and/or their construction phasing.

The traffic and revenue results presented herein are provided for feasibility considerations and to enlighten further policy discussions, and should not be construed as investment-grade projections. Better tools would need to be developed and applied with rigorous methods including independent review of assumptions at every stage to produce investment-grade projections suitable for securing a credit rating and obtaining toll revenue bond financing.

In the preparation of this Report and the opinions contained herein, PB makes certain assumptions with respect to such conditions that may exist or events that may occur that are subject to change in the future. These assumptions are made for purposes of modeling regional tolls and identifying a range of potential revenue, and are not intended to reflect any official decisions regarding new highway capacity investments. Although PB believes these assumptions to be reasonable for the purposes of this Report at the time of writing, they are dependent upon future events, and actual conditions may differ from those assumed.

EXECUTIVE SUMMARY

The Puget Sound Region's transportation needs far outstrip available funding, and increasing traffic congestion is adversely impacting our region's livability. This has led to a heightened call for new revenue sources to finance transportation infrastructure. User fees in the form of tolls have been a key element of this discussion, especially for the region's large scale "mega-projects". Technological advances in the area of electronic toll collection (ETC) has made roadway pricing more feasible by facilitating variable pricing to manage congestion and eliminating the traffic bottlenecks and land requirements of toll plazas. Tolling also has a key advantage over other transportation funding sources, in that it creates a direct linkage between project financing and those who use the roadway. And unlike a gas tax, the price of roadway use can be varied by roadway, time of day, type of vehicle, and even vehicle occupancy. Given sufficient autonomy in setting prices, a toll road owner/operator has the unique ability to manage traffic flows, prevent congestion, and thus, assure the traveling public of an efficient and reliable route.

Previous toll discussions have centered around the traffic and revenue impacts of tolling a single facility — either from a managed lanes approach whereby HOV lanes or new capacity is priced, or as the entire roadway. In either event, relatively little attention has been placed on the impact to other alternative highway routes. However, the traffic participation and resulting revenue arising from one tolled route is related to whether or not adjacent or alternative routes are also priced.

Two natural questions arise from this line of thinking:

(1) What happens to traffic demand on each facility if you toll all of the major highways within a given regional area; and

(2) What is the approximate range of potential toll revenue from a system-wide tolling of major facilities?

To help answer these questions and provide decision-makers with better information regarding the toll revenue potential from widespread highway pricing, this Regional Toll Revenue Feasibility Study was commissioned by WSDOT. Key findings of this study are presented on pages 12 and 13.

Study Objectives and Methods

The objective of this study is to model a regional toll highway network, including those facilities slated for "mega-project" capital improvements, in order to identify the potential range of revenue that might result from widespread value pricing to manage congestion. ***Policy issues regarding the tolling of existing federally funded interstate highways, toll restrictions of Senate Bill 6140, as well as the technological and administrative aspects of roadway pricing, including operational and maintenance costs, are not addressed in this study.*** The resulting revenue projections are intended to inform the policy discussion and assist decision-makers in determining if tolling has sufficient revenue potential and/or is an appropriate congestion management tool to merit further research, modeling and analysis.

For purposes of this regional pricing exercise, the introduction of tolls on a system of 131 miles of limited access highways in King and South Snohomish Counties extends to portions of seven facilities as listed in Table 1 and graphically depicted in Figure 1. Five of the seven facilities are proposed for various capital improvements, including:

- Replacement the earthquake damaged SR-99 Alaskan Way Viaduct;
- Completion of the south extension of SR-509;
- Capacity improvements to I-405 and SR-167; and
- Replacement of SR-520 bridge and connecting roadway improvements.

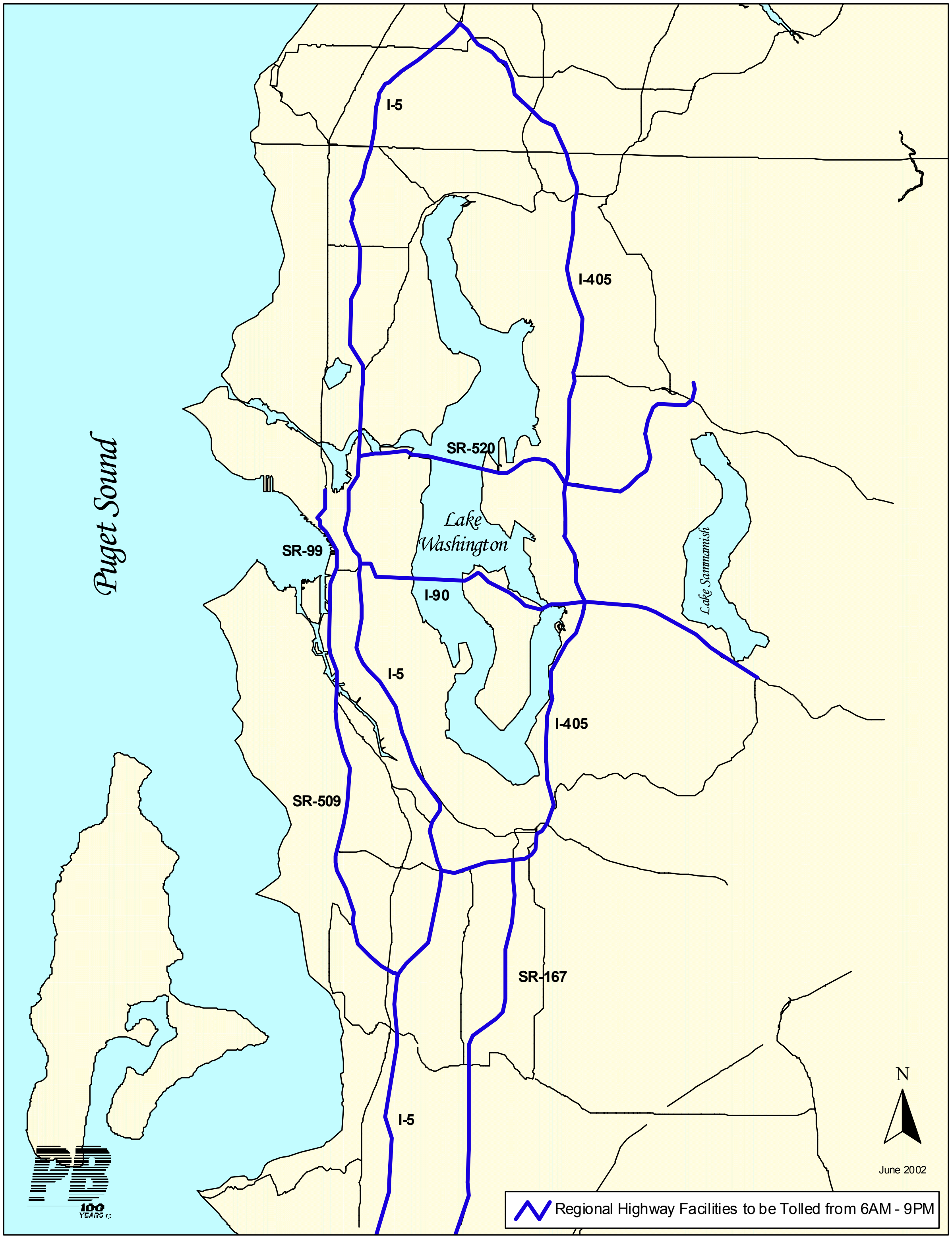
Only I-5 and I-90 are not being considered for major capital investments within the toll network boundaries; however, they will benefit from the other improvements, and to properly consider a balanced regional approach to value pricing and the best use of available highway capacity, they have been included in the toll network. It should also be noted that a limited access extension of SR-99 from Spokane Street south to the First Avenue South bridge and connecting with SR-509 was also included in the future network modeled. The assumed year of completion of the toll network and full implementation of tolling is 2014.

Table 1
Regional Toll Network Facilities

Toll Facility	*Extent of Tolling (North to South)*	*Toll Distance (miles)*
SR-99 / AWV	Roy St. to 1st Ave S.	6.1
SR-509	1st Ave S to I-5 at SR-516 I/C	11.8
I-5	North I-405 I/C to Pierce Co.	43.1
I-405	Entire Length	30.2
SR-167	I-405 to Pierce Co.	14.1
I-90	I-5 to SR-900	13.3
SR-520	Entire Length	12.8

The Puget Sound Regional Council's regional travel demand model and forecasting procedures were adapted for analyzing the regional toll network. While these tools represent best-practice methods for feasibility purposes currently available, this work is at the edge of their intended application, and moreover, the timing is such that this work does not benefit from work-in-progress improvements to the regional model.

Figure 1
Regional Toll Network as Modeled



In theory, the mechanism by which tolls are simulated within the regional model is relatively simple. On an un-priced roadway, users consider only their own travel time costs, and not the delay costs their vehicle imposes on other users. This behavior tends to result in roadway over-consumption and congestion, especially during peak demand times. Optimal travel behavior — that which theoretically minimizes overall network travel time — could be induced by applying tolls that are equivalent to the incremental delay imposed on others, with the revenues used to make cost-beneficial transportation investments. This is referred to as the "economically efficient" toll.

The modeling approach employed seeks to internalize the external time cost or incremental delay that an additional vehicle imposes on all other vehicles in the traffic stream. When users are compelled to consider this additional cost, some users alter their travel behavior, resulting in lower highway volumes, and higher resulting speeds. As roadway demand increases, the economically efficient or optimal toll also rises at an increasing rate to maintain reasonable speed and flow conditions, by inducing a sufficient number of would-be road users to seek alternative routes, modes, or times to travel.

Optimal Toll Rates

Optimal toll rates, expressed as time costs (minutes per mile), are derived from the model outputs for 46 analysis segments within the 131-mile regional toll network by two directions of travel and three daily time periods (AM peak, PM peak, and midday/evening off-peak) totaling 15 hours. These toll time costs are then converted to monetary rates by applying the average willingness to pay for delay reduction, expressed in dollars per hour. Research has shown that this value of time is approximately one-half of the average wage rate. For purposes of this study, the value of time was varied between one-third and one-half of the average wage rate for King County to create a range of monetary toll rates.

Table 2 presents the range of optimal toll rates per mile, by time period and facility, for the base and low values of time in 2014, the proposed year of full implementation. The toll rates are expressed in 2014 dollars and apply to single and two occupant vehicles. With few exceptions, transit and three-plus occupant vehicles are assumed to use toll-free HOV lanes at no charge or would otherwise be exempted from tolls. Trucks are tolled at a multiplier of the auto toll rates.

Table 2
Toll Rate Spectrum for 2014 in Inflated Dollars (Base Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.04	$0.22	$0.11	$0.04	$0.22	$0.11	$0.04	$0.04	$0.04
SR-509	11.8	$0.04	$0.14	$0.09	$0.04	$0.14	$0.09	$0.04	$0.04	$0.04
I-5	43.1	$0.04	$0.33	$0.14	$0.04	$0.21	$0.10	$0.04	$0.05	$0.04
I-405	30.2	$0.04	$0.19	$0.11	$0.04	$0.11	$0.07	$0.04	$0.04	$0.04
SR-167	14.1	$0.04	$0.20	$0.12	$0.04	$0.15	$0.09	$0.04	$0.04	$0.04
I-90	13.3	$0.04	$0.25	$0.13	$0.04	$0.18	$0.08	$0.04	$0.04	$0.04
SR-520	12.8	$0.06	$0.42	$0.19	$0.04	$0.28	$0.12	$0.04	$0.07	$0.05
Network	**131.3**	**$0.04**	**$0.42**	**$0.13**	**$0.04**	**$0.28**	**$0.09**	**$0.04**	**$0.07**	**$0.04**

Note: All amounts in year of collection dollars

Tolls are assumed to be levied electronically throughout the regional toll network. The AM and PM peak periods would vary in timing and duration by facility and location, but in no cases are less than three hours. Peak period toll rates range from 4¢ per mile to 42¢ per mile, with an average rate of 13¢ per mile in the PM peak and 9¢ per mile in the AM peak. Peak toll rates would vary noticeably by facility conditions, levels of congestion, and location to remain at their optimal levels. With reduced facility demand, the off-peak toll rates are generally lower, with an average toll of about 4¢ per mile. Off-peak tolls would apply to a midday window of time on weekdays, weekday evenings from 7 – 9 PM, and weekends from 6 AM – 9 PM. The network was assumed to be toll-free every day from 9 PM – 6 AM, both to give users an un-priced choice of travel, and also because, in most cases, traffic volumes are not high enough to generate optimal toll rates much above zero.

Toll Diversion Impacts

Application of the toll modeling methodology within the PSRC regional model results in lower vehicular traffic forecasts within the tolled general purpose lanes (excluding transit vehicles and 3+ HOVs).

Compared with the toll-free case, introduction of optimal tolls on a system of limited access highways in King and South Snohomish Counties will result in the diversion of some vehicle trips away from these facilities during the toll periods. These diverted trips fall into several categories:

- Travelers who make the same trip but divert to an alternate, un-priced route, usually another highway or arterial street;
- Travelers who continue to make the same trip on the tolled facility using their private vehicle, but traveling at a different time of day, when there would be a lower toll rate;
- Travelers who continue to make the same trip at the same time of day, but who will now travel in a vehicle that can use toll-free HOV lanes , either in a high occupancy vehicle with three or more occupants or in a bus;
- Travelers who will choose to change their trip behavior, either traveling to a different destination, such as one in a different direction that they can get to without using a tolled highway, or one nearer to their origin so that the shorter distance results in a lower toll charge to get there; and
- Travelers who opt to eliminate trips, either by not traveling at all, or by combining the functions of two or more trips into a single trip.

The average model diversion rates by facility due to the optimal tolls are shown in Table 3. Actual diversions rates vary somewhat by location, time of day and direction of travel for each facility. Note that diversion rates apply only to non-HOV travel; the actual change in highway traffic volumes is somewhat less due to some of the diverted vehicles converting to 3+ HOVs.

Note that the relatively low diversion rates for I-90 reflect the excess capacity and superior travel conditions of this facility relative to the SR-520 alternative, as well as the lack of alternatives for Mercer Island residents.

Table 3
Average Toll Diversion Rates by Facility (15-Hour Toll Period)

Toll Facility	*Toll Distance*	*Rates of Diversion* 2014	2020	2025	2030
SR-99	6.1	-11.8%	-12.1%	-12.4%	-12.7%
SR-509	11.8	-17.4%	-17.4%	-17.4%	-17.5%
I-5	43.1	-17.9%	-18.6%	-19.1%	-19.7%
I-405	30.2	-16.1%	-17.2%	-18.1%	-19.0%
SR-167	14.1	-18.0%	-18.4%	-18.6%	-18.9%
I-90	13.3	-6.4%	-6.4%	-6.4%	-6.4%
SR-520	12.8	-17.4%	-17.8%	-18.2%	-18.5%
Network	**131.3**	**-16.1%**	**-16.8%**	**-17.3%**	**-17.9%**

By way of comparison, a retroactive look at the SR-520 Evergreen Point Floating Bridge prior to eliminating the $0.35 toll in 1979 indicates that 16.2% of the post-toll traffic level was being diverted by the toll, with a little more than one-third of the diverted vehicles using I-90, and the remainder choosing other routes or not traveling at all. Incidentally, the $0.35 one-way toll on the SR-520 toll bridge when it opened in 1963 is equivalent to a $2.30 toll in 2014. The same toll, unchanged when removed in 1979, equates to $1.14 in 2014 dollars. By comparison, the model's average PM-peak toll rate for SR-520 is $0.19 per mile (Table 2), which equates to a toll charge of $1.34 for travel between I-5 and I-405. Average modeled toll rates and travel costs at other times of day are lower. This suggests that the regional toll modeling results for SR-520 are within the bounds of the historical SR-520 bridge toll rates when expressed in the same year's dollars.

The model processes for determining diversion, interpretation of the resulting diversion rates, and the impacts on the arterial system warrant further research and analysis. The regional travel demand model does an adequate job of estimating the overall levels of diversion, but it is less able to provide reasonable estimates of what would become of the diverted vehicles, particularly for diversion to arterial streets. The model is most able to estimate diversions to other routes and modes, and is least able to estimate diversions to other time periods or eliminations of trips.[1] Moreover, the model may not sufficiently discourage arterial street use as an alternative to a tolled highway as the arterials get congested. All of these factors suggest diversion may be over-estimated, which would result in both underestimated optimal toll rates and toll facility traffic volumes — both of which would tend to underestimate the revenue yield.

Nonetheless, examining the 2030 traffic forecast with and without tolls indicates that, at least on a daily basis, total vehicle miles traveled on the arterial system would not increase with the presence of tolls on the limited access facilities. However, there are bound to be individual arterial segments that would undoubtedly be loaded with increased traffic at certain times.

[1] Overall network demand remains relatively fixed in the regional model, which may not be a reasonable if trips are eliminated.

Revenue Projections and Considerations

The model-derived optimal toll rates were applied to the toll traffic volumes, expressed as vehicle miles traveled by analysis segment, to generated weekday revenue projections by direction and time period. A series of adjustments and factors were then applied to yield annual traffic projections. These include weekday-to-weekend day factors, weekday and weekend truck percentages to facilitate trucks paying a multiplier of the auto toll, and a five percent reduction to the overall volumes to reflect the potential for lost revenue from electronic toll collection (ETC) non-participation and/or evasion.

As shown in Table 4, a range of toll revenues were projected for the regional toll network from the year of implementation (2014) through the model forecast horizon (2030).[2] These forecasts represent potential gross revenues before any operations, maintenance and administration costs. The "high end" of the revenue spectrum is determined using the base value of time to derive the optimal toll rates, combined with the assumptions of weekend tolling at the off-peak toll rates and the tolling of trucks at an average toll rate of three times that paid by passenger vehicles. In this case, the term "high end" represents the top of the regional tolling revenue range for the given assumptions under the economically efficient toll methodology; it is not meant to convey the point of revenue maximization, and is in all likelihood below this point. The "low end" of the spectrum applies conservative assumptions, including the low value of time, an average truck toll rate of two times the auto rate, and no tolling on weekends.

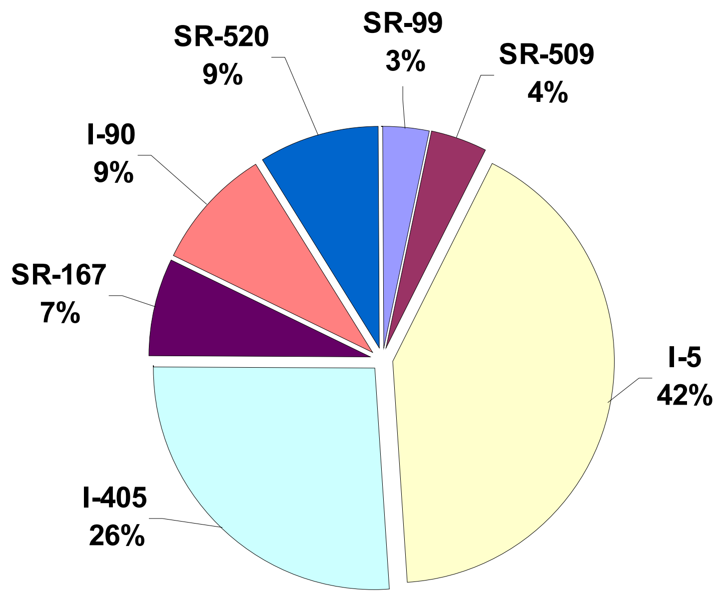
Table 4
2014 Projected Regional Toll Revenue Range in Inflated Dollars

Toll Facility	*Toll Distance*	*2014 Revenue Range in Inflated Dollars*	
		LOW END: Low Value of Time Weekends Toll-Free 2x Truck Toll Factor	*HIGH END: Base Value of Time Weekend Tolling 3x Truck Toll Factor*
SR-99	6.1	$8.5 M	$14.8 M
SR-509	11.8	$11.5 M	$20.1 M
I-5	43.1	$102.8 M	$189.2 M
I-405	30.2	$64.4 M	$119.0 M
SR-167	14.1	$17.9 M	$32.5 M
I-90	13.3	$24.1 M	$41.8 M
SR-520	12.8	$23.0 M	$40.0 M
Network	**131.3**	**$252.1 M**	**$457.3 M**

[2] For purposes of this exercise, it is assumed that all of the proposed network improvements, including a not yet contemplated limited access connection between the Alaskan Way Viaduct and SR-509, would be in place by 2014.

Figure 2 presents each facility's contribution to the regional toll revenue projection. It is important to note that each toll facility's revenue result would change, perhaps even substantially, if one or more of the proposed toll facilities were not priced.

Figure 2
2014 Distribution of Regional Toll Revenue by Facility

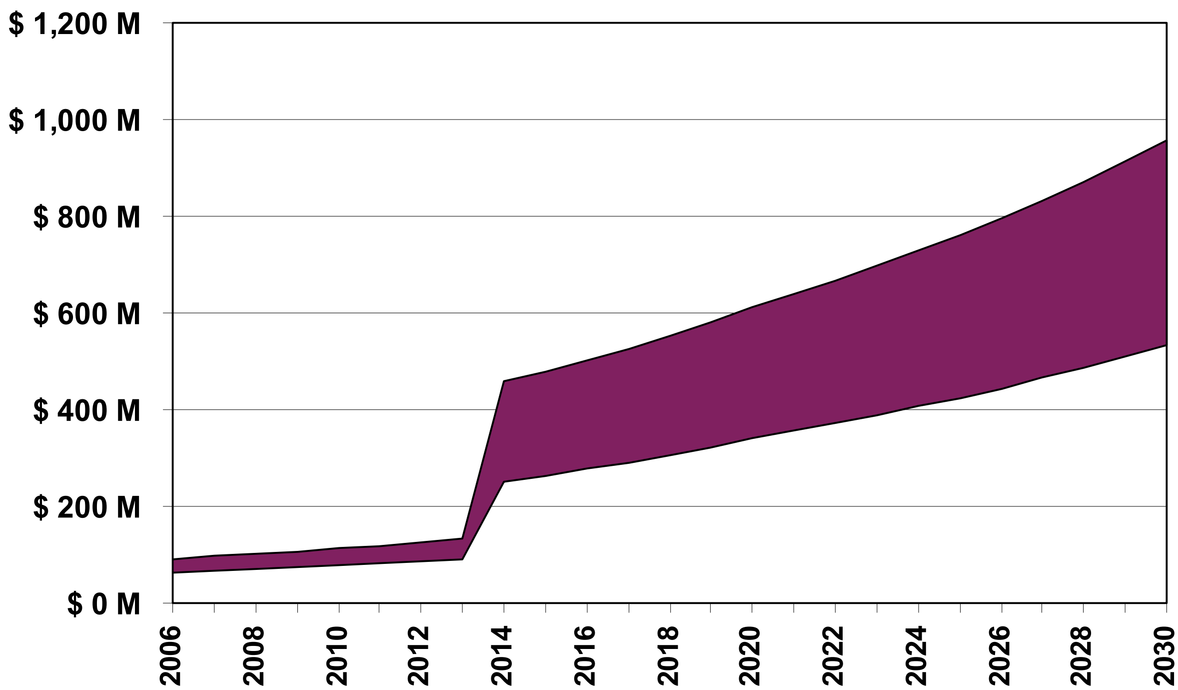


In addition, cursory consideration was given to the toll revenue that might be possible during a seven year implementation period from 2006 – 2013, as the proposed improvements are being put into service and toll usage is ramping up. In the absence of detailed information regarding project phasing and construction impacts, not to mention resources for the extensive additional modeling efforts had such information been available, a simplified partial revenue approach was adopted. In effect, toll revenues from 2006 – 2013 were estimated for the entire toll network using the off-peak toll rates, which are sub-optimal for the peak periods. This gives a revenue range of between $63 and 91 million in 2006, growing to between $91 and 132 million by 2013. In reality, if tolls were uniformly applied to the regional network during this period, the reduced capacity of those facilities undergoing construction could actually lead to higher real toll rates and lower highway traffic volumes than would be observed once the improvement projects were completed. However, there may be resistance to implementing the full optimal toll rates prior to completing the various network improvements.

It is interesting to note that the 2013 partial revenue method yields a result that approaches the I-5 contribution to the regional total revenue (shown in Table 4 for 2014). However, if I-5 were tolled singularly, it is likely that it would generate less revenue than as part of a regional system, although additional modeling work would be required to verify a range for this differential. Nonetheless, the simplified revenue estimate for 2006 – 2013 may be a rough proxy for implementing tolls on I-5 at the outset of construction through 2013. This might be a reasonable first option, especially for managing congestion on I-5, since although construction will be directed elsewhere, construction impacts on the other facilities, especially I-405, SR-99 and SR-509 would definitely cause diversion to, and thus worsened congestion on I-5.

Figure 3 presents the projected range of regional toll revenue from 2006 through 2030 in inflated, year of collection dollars.

Figure 3
2006-2030 Regional Toll Revenue Forecast Range in Inflated Dollars



Note that nominal annual revenue is shown growing at an increasing rate over time. This reflects both growing demand and a rising set of optimal toll rates on the regional facilities, the latter which are assumed to escalate for two reasons:

1. Growth in traffic demand will necessitate an increasingly higher optimal toll in order to elicit the appropriate travel behavior changes and diversion to maintain economically efficient network travel conditions and speeds; and

2. Over time, general inflation will increase the average wage rate, and thus users' value of time, the latter of which drives the calculation of the optimal toll rate to keep up with inflation.

This is an important outcome, and one that may prove challenging due to public resistance even after tolling is implemented. Failure to increase optimal toll rates for both value of time inflation and rising demand, particularly during peak periods, would eventually lead to the recurrence of congestion. Moreover, because value of time is variable, and may on the margin increase substantially over average values, it may be advisable to craft toll enabling legislation in such a way that allows the toll authority to set the lowest toll that keeps speeds no lower than some threshold. The value for this threshold would be determined in advance based upon the facility characteristics and desired operating objectives.

The methods employed provide ranges for economically efficient or optimal tolls that attempt to minimize overall network travel times, which generally result in toll rates below those that maximize revenue, but above those that pack the facilities for maximum vehicle throughput. However, these methods do not indicate where in this spectrum the modeled toll rates lie, nor do they give any indication of the elasticity of demand. As such, there is no way to pin down how much demand and revenue will change if the optimal toll rates are altered. Indeed, a much more comprehensive modeling effort, involving substantial market survey research and independent review of all modeling assumptions, would be required produce investment-grade toll traffic and revenue forecasts.[3] Nonetheless, the resulting range of annual revenues likely encases some portion of the true revenue potential, and can thus help decision makers ascertain if additional, more resource-intensive market research and modeling make sense.

Summary of Findings

- Travel levels on the highway network of King and South Snohomish Counties have reached critical levels relative to available capacity to make value pricing of this capacity a viable method to manage demand to prevent congestion and generate new revenue to fund transportation improvements.
  - Seven major highways in King and South Snohomish County totaling 131 miles were modeled as toll facilities for this study. This regional toll network differs from that included in Regional Transportation Improvement District (RTID) proposed by the County Executives of King, Snohomish, and Pierce Counties. Additional context information about the County Executives' proposal is included in the main report.
- Simulating tolls in the regional travel demand model for seven major highway facilities yields optimal toll rates that seek to *minimize overall network travel time* with the objective of economic efficiency. These toll rates are higher than those which would *maximize facility throughput* but lower than those which would *maximize toll revenue*.
  - The maximum throughput objective may sound appealing, but would likely be sub-optimal not only from a revenue standpoint, but also because it would spend more of the public's time at a higher total social cost to get the maximum number vehicles through than would result with a higher toll rate.
  - There may be cause to set tolls closer to revenue maximizing levels if other tolling objectives do not generate sufficient revenue to support the improvement expenditures.
- In the assumed year of implementation (2014), these toll rates range from 4¢ to 42¢ per mile in year of collection dollars, depending on the location, time of day and travel direction.
  - Peak period toll rates would typically average around 11¢ per mile, whereas off-peak toll rates would hover about 4¢ per mile.
  - The optimal toll rates will need to increase periodically due to both inflation and growing travel demand, if the roadway is to be managed to maintain optimal network results and avoid congested conditions. These toll increases will require that the

[3] For more information, see the Next Steps section of the main report.

operating objectives and management policies of the facility be well established and clearly communicated to the public and policy-makers. It may be useful to craft toll enabling legislation to allow the toll authority to set toll rates at the minimum levels designed to maintain a certain speed threshold.

- At the time of writing, general tolling of federally funded interstate highways is highly restricted. Implementation of any regional tolling concept would likely require that these restrictions be relaxed. There is some indication that this may occur in the next federal transportation funding authorization act.
- For 2014, the projected toll revenue is estimated to range from approximately $252 to $457 million per year in inflated dollars, depending on the underlying value of time assumption and various operating parameters, and before operating and maintenance expenses. This estimated annual range is expected to grow to between $535 and $955 million by 2030 assuming tolls escalate with demand growth and inflation.
  - The top end of this range applies the base value of time ($11.83 per hour), includes weekend tolling, and tolls trucks at an average rate of three times the auto toll, but does not represent the revenue maximizing situation. The assumptions underlying the top end of this range are not overly optimistic.
  - The bottom end of this range applies the low value of time ($7.89 per hour), excludes tolls on weekends, and toll trucks at an average rate of two times the auto toll. The assumptions underlying the bottom end of this range are fairly conservative.
- Implementation of tolls will cause travel demand on these facilities to decrease as those users whose cost of travel in time plus tolls exceeds the benefits from travel seek other options.
  - Some users will divert to other un-priced alternative routes, lower cost times of travel, closer destinations or lower cost modes (HOVs and transit). Others will eliminate their trips altogether or combine trips.
  - The model results may over-estimate the true diversion away from the toll facilities, which would tend to understate the optimal toll rates and toll revenue potential. Further research and model refinements would be needed to better understand diversion impacts, especially to the arterial street system.
- Additional policy and institution factors that need further consideration:
  - Potential diversion impacts to the arterial street network needs further study, including a detailed analysis of how diversion impacts arterials and consideration of local jurisdiction concerns and priorities.
  - Policy and legal issues regarding the tolling of existing facilities, be they interstate highways funded with federal dollars or facilities that do not receive improvements, need to be considered in the context of the interdependence of a regional toll network.
  - Further study of the technological and economic feasibility of implementing wide-spread electronic toll collection, including capital investment costs and ongoing operating, maintenance and administrative expenses, needs to be undertaken.
  - A detailed financial analysis is needed to gauge the appropriate capacity of the projected revenue stream for financing the system of proposed projects and related improvements.

INTRODUCTION

This report is part of a series of efforts to examine funding for regional highway capacity improvements. User fees in the form of tolls are receiving wide-spread discussion as a potential source of funding for at least four regional mega-projects — SR-99 Alaskan Way Viaduct replacement, SR-509 south extension, Trans-Lake Washington (SR-520) improvements and I-405 widening (including widening a portion of SR-167). The objective of this study is to enlighten this discussion and policy decision process regarding tolls by examining the traffic and revenue impacts of region-wide tolling. Specifically, the above four facilities slated for mega-project capital investments, combined with sections of SR-167, I-5 and I-90, have been modeled as toll facilities to assess the maximum revenue potential of roadway pricing. The intent is to help place the high book-end for revenue represented by a systems approach to tolling — both to add perspective to ongoing toll discussions, and to assist decision-makers in determining if roadway pricing could have sufficient revenue potential and/or is an appropriate congestion management tool to warrant further research, modeling and analysis on a more selected basis.

Recent advances in tolling technology, efficiency and acceptability have made roadway pricing a viable means to finance a broader range of transportation improvements. From a policy and management standpoint, the implementation of roadway pricing, along with sufficient autonomy to set toll rates, would give the Washington State Department of Transportation the capability to manage congestion and assure the traveling public that the priced facilities will always operate in a free-flow manner. While tolls may not be popular with everyone, they tend to be accepted as an efficient way to finance portions of transportation infrastructure by connecting part of the costs directly to those who use the facilities. In addition, technological advances in the area of electronic toll collection (ETC) has made roadway pricing more feasible by facilitating variable pricing to manage congestion and eliminating the traffic bottlenecks and land requirements of toll plazas.

Moreover, in this era of accountability in government, providers of new transportation infrastructure have a responsibility to the public to manage those resources in a socially efficient manner. The gridlock that has become ubiquitous on unmanaged facilities during peak times is predictably inefficient and imposes tremendous delay costs that increase the prices of goods and services and lower the quality of life for everyone. As demand continues to swell, additional management techniques including pricing need to be applied to help alleviate congestion, or at least mitigate growth to prevent the situation from worsening.

The following applies a relatively simple and efficient methodology for modeling regional highways as a toll facilities, taking into account future travel demands and users' willingness to pay for a facility that provides travel time savings and reliable commute times. It is intended to enlighten the discussion of how tolls might be used in these corridors and assess the revenue potential of implementing an optimal or economically efficient toll structure. And while the revenue forecast ranges offered are adequately precise to inform the decision process as to whether tolls make good technical and political sense, they are not purported to be sufficiently accurate to secure debt financing from the financial markets.

In considering the implementation of user fees in any corridor, it is important to keep in mind that there is a spectrum of operating objectives that can lead to a wide range of pricing strategies. Toll facilities may be operated to maximize revenue, to achieve a revenue target (perhaps linked to debt service and/or operating costs), to maximize travel benefits by minimizing overall network travel times, to maximize throughput of an individual facility, or to keep vehicle throughput within a target range. Minimization of network travel times (economic efficiency) and revenue maximization objectives may suggest varying toll rates by time of day, direction, and/or travel distance, whereas a revenue target may be achievable with a relatively simple toll structure. And just as different operating objectives suggest different toll structures, so to does the availability and quality of alternate routes. The more a priced facility reduces delay and provides a reliable, efficient transportation connection over other alternatives, the greater the willingness to pay by the traveling public.

Following the Executive Summary and this Introduction are five main sections — Methodology, Traffic and Toll Revenue Forecasts; Related Studies and Toll Facility Information, Next Steps, and Key Findings. A bibliography and an appendix are also provided.

METHODOLOGY

The toll modeling approach herein relies on the Puget Sound Regional Council's (PSRC) regional travel demand model. The PSRC model is a traditional four-step travel demand model that has undergone continuous refinement over the past two decades. At present, the model incorporates the base year and 2030 land use forecasts from the 2030 Metropolitan Transportation Plan (MTP) adopted by the PSRC in May 2001.

The existing PSRC model was previously refined for application to the Alaskan Way Viaduct (AWV) and Trans-Lake Washington projects.[4] This version of the PSRC model was further modified to incorporate specially developed procedures that were used to simulate and test the viability of tolling on highway facilities. In order to model region-wide tolling with the completion of the four mega-projects, a future network reflecting these improvements was coded into this version of the model. Table 5 on the following page summarizes the relevant facility network assumptions used in model coding as well as other relevant items, including extent of tolling, hours of tolling, and HOV/transit assumptions.

The approach for toll traffic and revenue modeling described herein represents a balance between the best theoretical technical methods, which are extremely resource and time-intensive to execute, and real world constraints regarding currently available tools and information, the early stage of the proposed projects, and a short timeline — all of which dictate a more pragmatic approach. Given a specific aim to determine the range of toll revenue that might be possible with widespread pricing to provide perspective and facilitate discussion — as opposed to developing resource-intensive "investment grade" toll revenue forecasts for purposes of securing financing from the bond market — this compromise approach strikes a reasonable balance. The results of this study should help to enlighten the ongoing policy discussion of user fees within the region, and to a lesser extent, on individual facilities, which may set the stage for further investigation and model refinement using more rigorous methods and their commensurate cost.

[4] See the Travel Forecasting Model Validation Report for Base Year 1998 prepared for WSDOT by PB, February 2002

Table 5
Future Network Modeling Assumptions

Attribute	SR-99	SR-509	SR-520	I-90	I-405 (incl. SR-167)	I-5
Alternative Modeled	Alternative D + limited access extension to SR-509	Preferred Alternative	6-Lane	Existing (No New HOV lanes)	Preferred Alternative	Existing + Committed HOV
# GP Lanes + # HOV Lanes per Direction	3 (including SR-509 to Spokane St extension)	2 + 1 (existing & new segments)	2 + 1	~3 + 1 (varies)	~4 + 1 (varies)	~4 + 1 (varies) 2 + 1 (express lanes)
HOV Lane Eligibility	No HOV Lane	HOV 3+ & Transit only	HOV 3+ & Transit only	HOV 3+ & Transit only	HOV 3+ & Transit only	HOV 3+ & Transit only
Toll Exemptions	Transit Vehicles Exempt	HOV 3+ and Transit (HOV Lane Toll-exempt in Model)	HOV 3+ and Transit (HOV Lane Exempted in Model)	HOV 3+ and Transit (HOV Lane Exempted in Model)	HOV 3+ and Transit (HOV Lane Exempted in Model)	HOV 3+ and Transit (HOV Lane Exempted in Model)
Extent of Tolling (South to North or West to East)	SR-509 to Roy St.	SR-516 to SR-99	I-5 to Redmond (SR-202)	I-5 to Issaquah (SR-900)	Tukwila (I-5) to Lynnwood (I-5) plus SR-167 to County Line	King / Pierce Co. Line to Lynnwood (I-405)
Hours / Days of Tolling	6 AM to 9 PM weekdays & weekends	6 AM to 9 PM weekdays & weekends	6 AM to 9 PM weekdays & weekends	6 AM to 9 PM weekdays & weekends	6 AM to 9 PM weekdays & weekends	6 AM to 9 PM weekdays & weekends
Trucks (all sizes)	Assumed to Pay a Multiplier of the Relevant Auto Toll Rate by Time Period					
Transit Service	Sound Transit Phase I + 1% Annual Growth in Bus Service					

The Puget Sound Regional Council (PSRC) approach to modeling tolls was developed by an outside consultant as part of a congestion pricing analysis for the 2030 MTP process. It simulates congestion pricing (tolling to manage flow) within the existing regional modeling framework. Specifically, it approximates the optimal "economically efficient" toll in such a manner that does not require significant market research regarding user demographics and preferences, and without having to re-specify the mode choice components of the model.

In order to fully understand this approach and the interpretation of the economically efficient toll, it is useful to consider the differences between various toll road operating objectives.

Toll Facility Operating Objectives

Differing operating objectives for toll facilities in the U.S. and abroad result in differing "optimal" toll rates or structures based upon the physical, technical and political characteristics of each situation. Four such recurring objectives considered in the modeling of toll facilities, which can at times be either compatible or conflicting, are:

1. Throughput maximization;
2. Revenue/profit maximization;
3. Revenue target (i.e., O&M cost plus debt service coverage); and
4. Economic efficiency in terms of congestion management.

Throughput maximization refers to a traffic engineering metric for an individual facility, measured in persons or vehicles per hour. This objective has a certain public appeal when considering the pricing of excess capacity in an HOV lane, the so-called High Occupancy Toll (HOT) lane approach. In a broader sense, this objective attempts to fully utilize the capacity of a facility by serving the most travelers possible. The assumption here is that in an un-priced situation, demand exceeds capacity such that severe congestion results, causing flow to breakdown. Pricing is thus required to maximize throughput and prevent unstable flow conditions. Maximum throughput occurs at the point just prior to flow breakdown, where a marginal increase in demand disrupts traffic flow, causing it to become unstable. For multi-lane freeway facilities, maximum throughput corresponds to traffic volumes that result in speeds of approximately 45 mph. Pricing or other demand management tools must be sufficiently precise and dynamic to prevent flow breakdown under this operating objective. In practice, this operating objective may require the use of a throughput target that approaches but falls short of maximum throughput to provide a sufficient margin of error against crossing over the line into unstable flow conditions. In addition, this objective will not result in an efficient balance between total travel time and cost, particularly when considering that a higher toll could improve travel times and provide more revenue to be re-invested into capacity improvements or other investments to benefit those who choose not to pay the tolls.

Revenue maximization, or **profit maximization**, which is a form of revenue maximization subject to a cost function, capitalizes on users' willingness to pay for the toll road's attributes — primarily time savings, as well as convenience, reliability/predictability, safety, etc. Tolls are set to maximize net revenue taking into account the relationship between travel time savings and willingness to pay, and only a fraction of all travelers during peak periods will choose to pay. If throughput maximization is at one end of the spectrum of toll rates and volumes, revenue maximization is at the other. The latter objective tends to result in tolls that are notably higher and facility volumes that are notably lower than throughput maximization, along with speeds that tend to be at or near free-flow (speed limit) conditions. However, these attributes lead to high rates of diversion to alternate routes, and overall network travel times will not be optimized.

The **revenue target** objective seeks to achieve a particular threshold, such as sufficient revenue to cover the toll facility's operating and maintenance costs (O&M) and ongoing debt service expenses by a reasonable margin, or alternatively to fund some other objective such as transit service in the same corridor. To the extent that the target is less than the maximum revenue attainable, this objective results in a lower toll rate, and thus a higher traffic volume than the revenue maximizing objective. Also, since debt payments are often fixed, and increasing O&M cost may be offset by growing traffic demand, this objective may be associated with toll rates that do not increase regularly with inflation.

The **economic efficiency** objective uses tolls to correct for the economic distortion or market imperfection that occurs with an un-priced highway facility, resulting in over-consumption of the roadway by users that do not fully perceive all marginal costs of their use. An individual user entering an un-priced roadway perceives only his or her own personal delay or time costs, and not the "external" impacts that his or her vehicle imposes on the traffic flow, despite the fact that this results in additional delay to other users. The latter impact on other travelers is an economic externality — a cost or benefit of a market transaction that is not reflected in the prices consumers and suppliers use to make their decisions. In this case, the market "transaction" is use of the road for travel, the consumer is the individual roadway user, the "price" is the individual's travel time or time cost for the road use, and the supplier is the road owner. Because a user's travel choices do not consider the incremental delay they impose on others, a negative externality results.

A price signal in the form of a toll can be used to get the user to recognize the delay they impose on others in making their own travel choices. Tolls are set to the levels that allow only those users whose benefits of travel equal or exceed the marginal costs of travel. In the short run, ignoring pricing issues for auto use, the marginal cost of vehicular travel is the sum of the private travel time cost for that vehicle plus the social delay cost it imposes on other vehicles. In other words, the efficient toll is defined as the one at which the user is paying a price that equals the true short-run marginal cost of travel. Since the user's private costs are "paid" in time, the actual monetary "efficient" toll rate for this objective is the amount that causes users to fully consider the social delay costs that their travel decisions impose on other users of the roadway.

On an uncrowded facility, the addition of another vehicle has a negligible effect on the travel time for the relatively few existing vehicles. With excess capacity, the external cost represented by the economically efficient toll is very low as delay externalities are too insignificant to matter. However, the external cost or incremental delay factor rises with volume and can become quite substantial as the facility approaches capacity, when its performance under congestion deteriorates rapidly with additional demand.

Assuming that users have perfect information about pricing, that toll revenues are used to make cost-beneficial highway investments, and that pricing is ubiquitous, then short-run marginal cost toll pricing allows the road network to operate with maximum net social benefits from the resources used to build and operate roads. In this case, the economically efficient toll rate **maximizes travel time savings**, which for a given volume of traffic, **minimizes total network travel time**.[5] In theory, toll rates resulting from the economic efficiency objective would lie somewhere between the revenue maximizing toll and the throughput maximizing toll.

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[5] Note that the proper measurement of total travel benefits includes the toll revenues since some of the time savings are captures by the tolling authority and returned to all users in the form of cost-beneficial highway investments.

In practice, this operating objective is difficult to measure and achieve, making it difficult to know where in the spectrum the estimated toll rate lies. Market imperfections, incomplete information, and less than ubiquitous tolling lead to sub-optimal behavior and increased diversion, and may result in toll rates that are higher than intended. Nonetheless, the more diversion opportunities are contained, and the more inelastic demand is (the more captive the user is, as would be the case during peak periods), the narrower the spectrum between the revenue maximizing and economically efficient toll rates.

Applying Tolls within the PSRC Regional Model

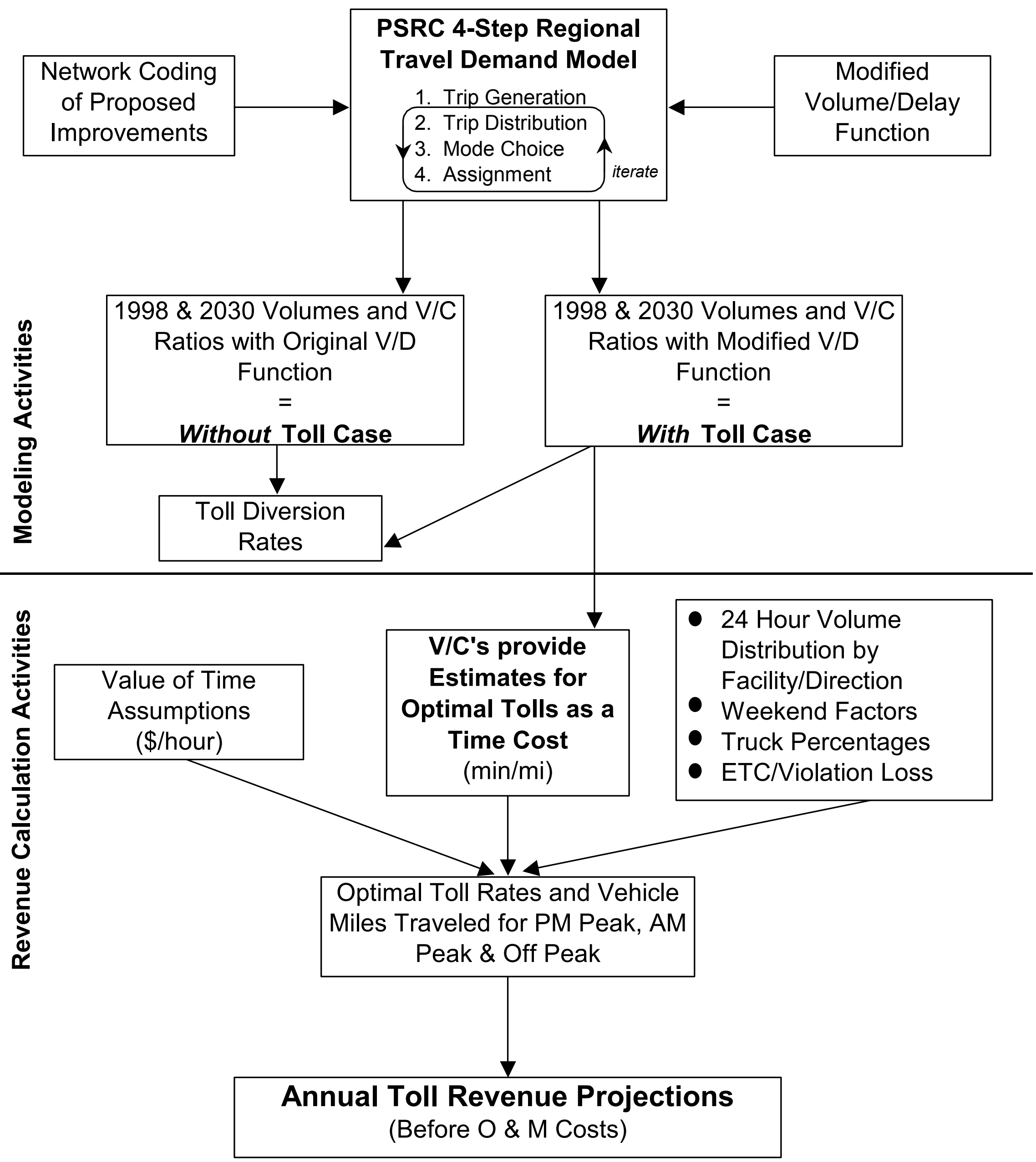
The PSRC approach for simulating tolls/congestion pricing within the regional travel demand modeling framework is theoretically equivalent to the fourth operating objective above , that of economic efficiency. In reaching equilibrium, the traditional four-step PSRC regional model attempts to minimize overall network travel times, subject to various constraints including an essentially fixed level of demand by analysis year. The same is true when tolls are added as an additional time cost or impedance to the network links that represent toll facilities. When demand is assumed to be relatively fixed, minimization of network travel times is equivalent to maximizing travel benefits (time savings), which is the objective of the economically efficient toll rate.

Roadway pricing is introduced by adding an impedance increment to travel times used in the regional model (in the form of a time cost that is convertible to a monetary toll) that brings the total impedance up to the level that reflects the true incremental impedance, rather than just the impedance perceived by each user. This is done by modifying the mathematical specification of the model's volume-delay function(s) to incorporate not only the "own" delay, but also the additional delay imposed on other vehicles on a link by link basis.[6] The greater impedance perceived on the toll links causes diversion to non-toll links by those users for which the additional toll time cost triggers total costs to exceed the toll facility's travel benefits, though actual travel times improve. It is important to note that within this application of the PSRC regional model, overall demand does not change in response to tolls; rather, the model redistributes demand in a different manner among alternative routes, which also results in some trips being shortened.

Figure 4 on the following page summarized the overall toll modeling methodology.

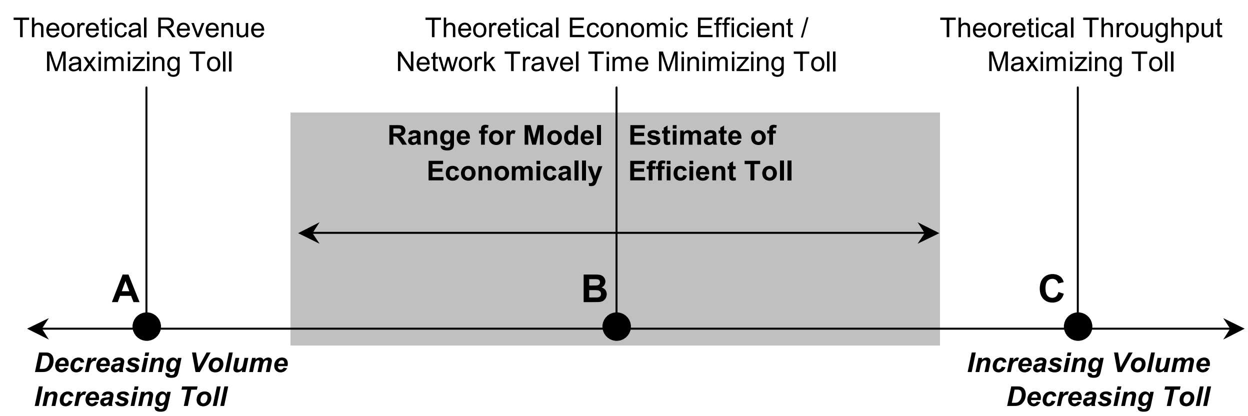
[6] The reader is referred to PSRC's Transportation Pricing Alternatives Study — Technical Memorandum 3: Simulating Congestion Pricing in EMME/2, which details the mathematics of the modification to the model's volume delay function.

Figure 4 Tolling Methodology



In practice, limitations of the model framework and in the assumptions for applying the economically efficient toll structure rarely yield true economic efficiency. Rather, the model estimate for the economically efficient toll rate may fall in a range between the theoretical revenue maximizing toll rate and the throughput maximizing toll rate. To the extent that tolling is more pervasive or ubiquitous, and/or diversion to alternate (un-priced) routes is minimized, the model estimate for the economically efficient toll will converge on the true value, whereas the more isolated tolling is and the more prevalent are diversion opportunities, the more likely the model estimate for the economically efficient toll will diverge from its true value. Figure 5 illustrates the various toll road operating objectives and the range for the model estimates for optimal toll rates.

Figure 5
Toll Rate and Volume Relationships of Theoretical Tolling Objectives



Assessment of the Optimal Toll Time Cost

Since the PSRC regional model's volume-delay function is a function of link volume-to-capacity (V/C) ratios, given an assumption for the desired free-flow speed, the optimal toll for each link and direction — expressed as a time cost per mile — can be derived based solely on the model output V/C ratios. The marginal cost of delay equation is provided below, with Table 6 illustrating the one-to-one correspondence between selected V/C ratios and the optimal toll, as a minutes per mile time cost, for a facility with an assumed free-flow speed of 60 mph. Figure 6 on the following page plots the volume-delay relationships with and without consideration of the external delay costs.

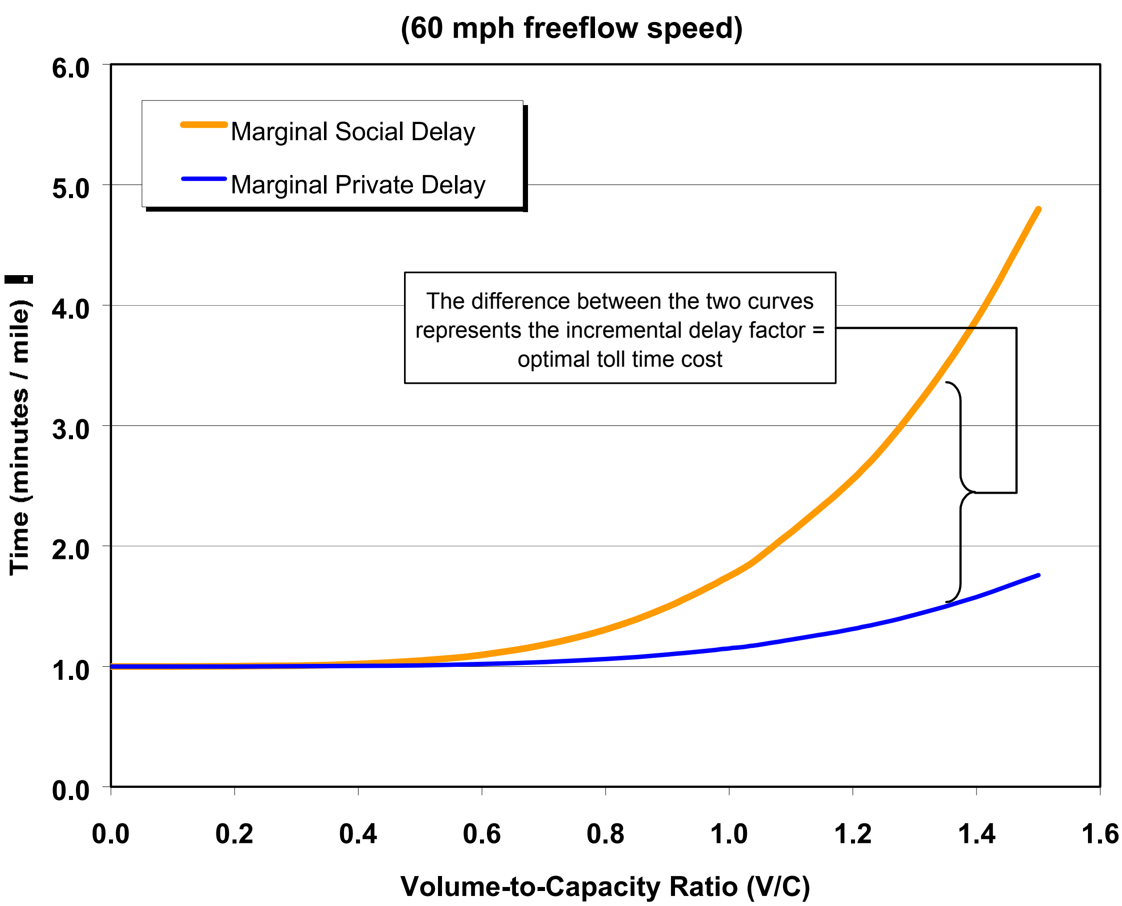
$$m(v) = \underbrace{t_0\left[1 + 0.15\left(\frac{v}{c}\right)^4\right]}_{\text{private "own" delay cost}} + \underbrace{\left[t_0 \cdot 0.6\left(\frac{v}{c}\right)^4\right]}_{\text{external delay cost = toll time cost}}$$

where $m(v)$ = marginal social cost of an additional vehicle
t_0 = free-flow time for a link distance (speed)
v = hourly traffic volume for all lanes
c = hourly capacity, all lanes

Table 6
Optimal Toll Time Costs by V/C Ratio for a 60 mph Facility

V/C Ratio (60 mph free-flow speed facility)	*Incremental Delay Factor = Optimal Toll Time Cost (minutes / mile)*	*V/C Ratio (60 mph free-flow speed facility)*	*Incremental Delay Factor = Optimal Toll Time Cost (minutes / mile)*
0.0	0.000	0.8	0.246
0.1	0.000	0.9	0.394
0.2	0.001	1.0	0.600
0.3	0.005	1.1	0.729
0.4	0.015	1.2	1.244
0.5	0.038	1.3	1.714
0.6	0.078	1.4	2.305
0.7	0.144	1.5	3.038

Figure 6
Volume-Delay Functions for "Own" and "Total" Vehicle Marginal Delay



The difference between the two curves in Figure 6 indicates the optimal toll time cost for the resulting model V/C ratio for the with toll case. For every model link in which tolls are applied, the modified volume-delay function results in a with-toll V/C from which that link's toll rate can be derived. Note that the higher the free-flow (design) speed for the facility, the lower the "optimal" economically efficient toll, all else equal. For example, at a V/C of 0.9, the optimal toll time cost is 0.394 minutes per mile for a 60 mph facility, as shown in Table 6. In contrast, a 50 mph facility yields a toll time cost of 0.472 minutes per mile at a V/C of 0.9. At first glance, this result seems counter-intuitive, based on the logic that a higher speed would generate additional time savings over alternative routes, and thus, a higher toll/greater willingness to pay by users. In a static sense, this is true, though in reality, there are several dynamic factors at work that can make the resulting toll rate go either direction. A 60 mph facility would tend to have a higher capacity than a 50 mph facility. Therefore, at a V/C ratio of 0.9, the 60 mph facility not only moves more vehicles, but also has greater room for additional vehicles, and thus the time cost that one additional vehicle places on all other vehicles — the optimal toll time cost — is smaller.

The future network applied for regional tolling of the seven facilities modeled with pricing assumes that all of these facilities would have a free-flow or design speed of 60 mph.

Estimating Values of Time

Since tolls within the modeling framework are expressed as time costs per mile, it is necessary to convert these to monetary amounts using value of time information. In this context, value of time is defined as a roadway user's willingness to pay to avoid delay, measured in dollars per hour. Value of time has been shown to be closely related to household income levels or average wage rates; in fact, there is evidence that, for commute trips, the ratio of in-vehicle travel time to the wage rate is generally constant across a wide range of income levels. The challenge lies in estimating an appropriate value of time for setting toll rates, because a person's willingness to pay to avoid delay varies by income, trip purpose, peak versus off-peak times of day, travel mode, level of traveling comfort, and even with the level of congestion, which increases travel time uncertainty.

The literature on the value of travel time is extensive and well developed; Small (1999) provides an excellent review of current research. Values of time in research studies are most often determined by conducting stated preference survey (SPS) techniques in which travelers are asked about their willingness to pay for various trade-offs regarding expected travel time and variability. Mode choice models are estimated using the SPS results and the marginal rates of substitution between the costs and travel times of alternatives choices are evaluated. Alternatively, attitudinal panel studies can be used to assess values of time and willingness to pay for delay reduction and/or travel time reliability. A panel study uses repeated surveys of the same sample of users over time to track household income, trip making and travel behavior, route choice, etc., and infers values of time based upon repetitive revealed behavior. This method is particularly useful for assessing values of time for route choices that involve an existing toll facility, and has been employed as part of a series of studies for the I-15 Congestion Pricing Project in San Diego.

In considering the application of tolls on major highway facilities within King and south Snohomish Counties, the necessary market research of users and resulting studies have simply not been done for this or any comparable groups of users. Given this study's objective to assist decision-makers in examining region-wide tolling impacts with an eye toward evaluating if further research, modeling and analysis is warranted, it is necessary to draw upon the experience of studies in other areas to estimate values of time for area travelers. This is typically done by relating the value of time to average wage rates in other areas and then applying the resulting proportion to local wage rates.[7] The experience of other toll facilities, especially those that are dynamically priced adjacent to a parallel un-priced roadway (e.g., SR-91 in Orange County, California) can also provide useful information on willingness to pay.

Several studies have been undertaken to measure value of time. Supernak (2001) summarizes a review of these studies, noting the following.

> Cambridge Systematics (1977) estimated that commuters in the Los Angeles area valued in-vehicle time for non-business travel at 72 percent of their wage. MVA Consultancy (1987) estimated that the value of time of commuters in England varied between 22 and 55 percent of gross wage for high-income earners, and over 100 percent for the lowest income earners. Hensher (1989) estimates a value of time for Australian commuters at 28 percent of their gross wage. Small (1992) summarizes these and other studies, with the conclusion that a "reasonable average value of time for journey to work is 50 percent of the gross wage rate."

One of the challenges in estimating and measuring value of time is understanding what exactly it represents a willingness to pay for, as factors other than delay reduction that may be "hidden" in the value of travel time if not controlled for separately. For example, if other travel characteristics such as comfort/convenience or travel time reliability are not controlled for, then their values may be reflected in the "observed" value of time, making the measure less than ideal for comparing modes and route choices. Congestion often increases the willingness to pay for travel time reductions — here the congestion is increasing willingness to pay to reduce uncertainty, in addition to reducing delay. This suggests that the selection of a appropriate fraction of the prevailing wage rate to serve as the value of time, when based on toll experience elsewhere, should take into account all the attributes users were paying for, which may be more than just delay reduction.

Some interesting results have come to light based upon studies of SR-91. The Cal Poly Applied Research and Development Facilities and Activities (ARDFA) transportation research group conducted a three year series of studies on the impacts of the SR-91 Variable Toll Express Lane facility that opened on December 27, 1995. Objectives included evaluating the impacts of variable-toll express lanes along SR-91 in California while also gaining insight into traveler's reactions to market-based road pricing as a solution to increasing congestion along California's highways. Relevant findings included:

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[7] In 2000, the average wage rate in King County was $23.66 as estimated from Washington State Employment Security Department data on covered employment and total wages and salaries paid.

- There exists a strong correlation between tolled express lane patronage and travel time savings. In spring 1997, the percentage of SR-91 travelers who used the express lanes ranged from about 7% in the mid-day off-peak, when time savings were minimal, to a high of 35% during the peak hour when delay to freeway users was an estimated 12-13 minutes. These observations imply a value of time for SR-91 commuters of $13-14 per hour. However, implied values of time across points in time vary substantially.
- Despite the correlation between travel time savings and the percentage of SR 91 traffic using the toll lanes, some toll lane users choose to use the toll lanes under traffic conditions where the expected value of their time savings is clearly less than the tolls paid. Driving comfort and the perception of greater safety were cited by travelers as the principal supplemental benefits motivating this behavior.
- Surveys conducted with SR-91 peak period travelers provide evidence that many commuters overestimated their true time savings when using the express lanes. This implies that actual values of time may be less than studies have estimated, or that users are "valuing" other travel attributes such as reliability in their travel time savings estimates.

Market research and mode choice model estimation for SR-15 in San Diego suggest a mean value of time of about $16 per hour, although it is noted that the population using this corridor is relatively affluent. In this case, the models did not separately control for travel time reliability, such that the value of "time savings" also includes the value of those unmeasured reliability improvements that generally go along with them for toll facilities.

Finally, there is considerable evidence that the distribution of time values varies considerably from the average value, both across users as well as across trip purposes and times of day. On the margin, values of time, and thus willingness to pay tolls, can significantly exceed their average values. Examples include wage-earners who can ill-afford to be late for work; travelers on the way to the airport, and commuters on their way daycare facilities, who will incur substantial monetary penalties if they are late picking up their children.

Values of Time Assumed in the Optimal Toll Rates

Current literature generally converges on a value of time for work trips equal to 50% of average wage rates for the relevant travel market area (Small, 1999 & 1992, and Waters, 1992). It is recognized that this value primarily represents a willingness to pay for delay reduction, but may also include a willingness to pay for reducing uncertainty, improving comfort, and other attributes generally associated with toll facilities and value pricing. In King County, the most recent available employment data from the Washington State Employment Security Department yields an average wage rate of $23.66 per hour for the year 2000. One-half of this amount, or $11.83, was thus established as the "base value of time" and used to generate toll rates per mile from the optimal toll time costs.

An additional "low value of time" was also established at one-third the average wage rate, or $7.89 per hour for two reasons. First, it is recognized that other previous studies in the Puget Sound region, notably the I-405 EIS effort, have assumed values of time closer to one-third the average King County wage rate. Second, a "half wage rate" value of time may include willingness-to-pay factors for other travel attributes beyond reducing delay, which may or may not vary between tolled and un-priced routes.

Since the true value of time for regional travelers is yet unknown, the use of two values yields a range that likely includes the relevant average value. Two time values also yields two sets of optimal toll rates, which helps to bracket the resulting revenue forecasts within a range that is more likely to include the true revenue possible. However, in this context, two sets of optimal toll rates do not allow us to test the toll elasticity of demand nor do they impact the expected traffic volumes. Rather, they merely allow us room for error in estimating users' willingness to pay for delay reduction.

Finally, considering that the proposed projects and full implementation of tolling will not take place for several years, the value(s) of time underlying the set of optimal toll rates will need to be inflated to year-of-opening dollars to yield the correct revenue estimates.

Limitations of the Toll Modeling Approach

A key question raised by policy-makers when considering the implementation of a toll facility is how traffic and revenue will be impacted by changes in toll rates. At heart of this question is the concept of toll elasticity of demand — how travel behavior changes with varying toll rates, holding all other variables constant. Demand is said to be inelastic if a *given percentage increase* in the toll rate results in a *smaller percentage decrease* in traffic volumes. When demand is inelastic, marginal increases in the toll rate will generate additional total revenue. Conversely, when demand is elastic, the resulting percentage drop in demand is larger than the percentage increase in the toll, and overall revenue drops. Normally, the demand for any good or service is inelastic at relatively low prices, but becomes increasingly elastic as prices rise. At some price in between, revenue is maximized.

Furthermore, demand becomes more elastic over time as people seek alternatives or reevaluate their travel behavior based upon their own costs and incentives. Thus the toll structure that may maximize revenue in the short-run may become sub-optimal in the long run

Although the methodology developed for the PSRC is intended to identify the optimal or economically efficient toll structure which seeks to minimize overall network travel times, it does not tell us how close or far this is from the revenue maximizing toll, and it cannot tell us by *how much* demand, and thus, revenue will change at different toll rates.

Detailed market research and the specification of a toll mode choice model — both of which would be required to estimate elasticities of demand — are not currently part of the PSRC methodology for simulating congestion pricing within the modeling framework. In the event that the revenue results of this feasibility study are sufficient to warrant the further research and expense, the Next Steps section of this report discusses the steps required to take the traffic and revenue forecasts to the next level.

Land use forecasts used in the regional model, both in terms of quantity and location, are largely a policy exercise based on historical trends and desired growth patterns. In this particular effort, the accuracy of the location of growth is more of a concern than the quantity.

With a 2030 forecast year and a largely urbanized area, the actual quantity of growth is of lesser importance as the area converges on full build out. Assumptions of the location of growth can impact the toll modeling by causing some facilities to experience higher or lower demand levels than others, and in consequence, different toll rates and revenue levels. To some extent this effect is tempered in this study due to the assumption of system-wide toll network, which has a balancing effect. This suggests that a finely-cut intra-facility level of analysis will be less accurate than a broader-level view of the network.

The regional model used for this analysis does not interactively link land use and transportation system characteristics. For instance, future land use patterns are assumed to be fixed, with no land use response to variations in the toll rates or the roadway network. However, the net effects of this consideration may be moderated due to the system-wide tolling approach.

While some base year model inputs are changed to arrive at the future projections, other base year validation parameters such as trip rates and mode choice coefficients are assumed to be fixed over time. The implementation of a regional toll network presents a noteworthy change to the system that the model may not fully capture. The application of an impedance to each link as a surrogate for an actual monetary cost of a toll may have some application limitations in accounting for changes in behavior.

TRAFFIC AND TOLL REVENUE FORECASTS

Given that the purpose of this study is to enlighten the ongoing discussion of tolling rather than provide "investment-grade" revenue forecasts, the approach here is to establish a range that likely encases the toll revenue potential of regional pricing and is informative to further policy decisions. The determination of the revenue range involves varying three key parameters: (1) optimal toll rates were varied by applying the two different values of time, (2) the base toll multiplier applied to trucks was varied, and (3) additional variation was generated by estimating revenue with and without tolling on weekends.

Regional Toll Modeling Assumptions and Application

The highway network of the PSRC Regional Travel Demand Model was prepared for modeling the future build-out scenario indicated in Table 5 for both the base year (1998) and the forecast year (2030). This required taking the future 2030 highway network — which includes all committed and funded regional projects in the PSRC, WSDOT and local Transportation Improvement Plans — and further codifying the proposed improvements resulting from the SR-509 extension, SR-99 Alaskan Way Viaduct replacement, SR-520 Trans-Lake and I-405 widening mega-projects. All of the toll network facilities in this future network were assumed to have a free-flow speed (speed limit) of 60 mph.[8]

Though not part of the SR-509 extension project nor the underlying 2030 network, HOV lanes were coded on the existing portion of SR-509 to give the entire facility two general purpose and one HOV lane per direction. Similarly, SR-99 was coded as a limited access facility of three lanes in each direction between the end of SR-509 at the First Avenue South Bridge and Spokane Street to match with the proposed Alaskan Way Viaduct improvements, even though the former is not part of the latter project. These network assumptions effectively create a contiguous "west corridor" alternative to I-5, thus attracting more traffic from I-5 to SR-509/SR-99 than would otherwise be the case.

Figure 1 in the Executive Summary depicts the regional toll network as modeled. The network was further assumed to include portions of I-5, I-90 and SR-167 in combination with the four mega-project facilities above. This assumption is practical for two reasons. First, by eliminating the high capacity, un-priced alternative facilities, the overall distribution of traffic remains relatively evenly balanced across available highway capacity. Second, it generates significantly more revenue, which is in keeping with the objective to identify the upper bound of revenue potential from a broader regional perspective, recognizing that individual facilities interact as components of a system.

The overall modeling objective was to model the 2030 highway network, for both the base year (1998) and the future year (2030) demand conditions, in order to have two reference points from which to interpolate intermediate year values. Considering model runs with and without tolls, this gives four model scenarios. In addition to the highway network, the future transit network

[8] Note that a lower free-flow speed assumption results in higher optimal toll rates, and thus, more optimistic revenue projections.

was fixed at the 2030 level for modeling both reference years. This was considered to be a conservative assumption, since the 2030 future level of transit service applied to an earlier year will tend to overstate transit usage, and thus understate auto usage, which would result in lower highway demand and toll revenue. Note that the 2030 transit network is defined to include existing service changes since 1998, transit operators' six year plan service improvements through 2007, and a one percent per year increase in transit service thereafter through 2030. In addition, the 2030 transit network assumes the Sound Transit LRT line from Seatac to Northgate as well as services in Phase 1 of the Sound Move Plan.

Although the highway and transit networks were fixed at their 2030 levels, all other model inputs were allowed to vary between the two reference years. For example, the base year model runs utilized the current origin-destination trip matrix representing present demand levels, as well as the existing land use patterns, population and employment, auto operating costs, parking costs, and other system attributes. All of these inputs take on different projected values for the 2030 model runs.

For the "without toll" scenarios, the regional model was run with the standard volume-delay function in order to generate the traffic volumes and corresponding volume-to-capacity (V/C) ratios necessary for identifying the incremental time costs that correspond to the economically efficient "optimal" toll rates.

In addition, the "with toll" scenarios were modeled with the modified volume-delay function which adds an additional impedance corresponding to the external time delay component to simulate the case with the optimal toll in place. The resulting volumes are used to project toll revenue, and can be compared to the without toll volumes to estimate the gross diversion to alternate routes caused by the implementation of tolling.

Revenue Calculation Assumptions

Tolling Mechanism

The following presents some general assumptions regarding the processing of the model outputs and resulting traffic forecasts; the revenue calculations and related facility operating attributes; and the factors that contribute to a range for projected toll revenue under the future build conditions. These assumptions are made for purposes of modeling regional tolls and identifying their upper revenue range potential, and are not intended to reflect any official decisions regarding new highway capacity investments.

The traffic and toll revenue forecasts in this study reflect the assumption of 100% electronic toll collection (ETC). In addition, based upon the methods used to model tolls, it was most appropriate to assume that tolls would be charged on a per-mile basis. In other words, users would be charged only for the distance they travel rather than assuming a set of flat toll rates that simply buy access to specific roadway segments. With ETC, this latter assumption poses no technological challenges that could not be overcome.

Although the ETC and per-mile tolling assumptions are convenient for this modeling exercise, given the nature of regional travel and the myriad of access points within the toll network, it would be practically impossible to consider any other tolling schemes. Manual toll collection and/or flat rate tolls would have tremendous real estate requirements and could be very labor-intensive, not to mention the queuing delays at various toll plazas. A non-trivial amount of toll evasion would have to be tolerated with so many access points, and flat toll rates could require charging cash customers the full amount associated with the maximum potential travel distance to the next toll plaza, regardless of how far they actually travel. While it is not an objective of this study to solve the technological challenges of region-wide toll collection, it is safe to say that manual toll collection is not likely feasible.

It is recognized that the majority of vehicle-trips, if not users, on the regional toll network would be made by local residents who would likely obtain the necessary ETC vehicle transponders. All the same, there will be some infrequent users, visitors, and even regular users who, for whatever reason, will not have transponders and who would thus be excluded from ETC. It is anticipated that license plate recognition technology would be used to bill the registered owner for applicable toll charges plus any administrative fees.[9] It would also be possible to equip rental car fleets with the necessary transponders and have toll charges added to the user's rental fee. Nonetheless, a 100% ETC system will likely deter some travel and/or cause inadvertent or intentional toll evasion. To account for these potential non-revenue trips made by such users — without considering alternative payment methods or enforcement mechanisms/costs — the toll revenue forecasts were conservatively reduced by 5%. It is assumed that this revenue adjustment would compensate for the revenue loss associated with 100% ETC.

In addition, no assumptions have been made regarding the operations and maintenance costs of electronic toll collection, administrative costs of toll collection including billing of vehicles without transponders, or violation enforcement. The revenue ranges reported reflect gross toll revenues before consideration of any such costs. Estimation of operating, maintenance and administrative costs for region-wide tolling are beyond the scope of this study.

Toll Periods, Toll Rates and Implementation Timing

Year 2014 is the assumed year of opening for the four mega-project investments. To the extent that this date is optimistic, it will understate the annual toll revenue potential. The 1998 base year and 2030 forecast horizon have been used to interpolate 2014 volumes, and thus, V/C ratios and optimal toll rates for this opening year and other intermediate years through 2030.

In addition, cursory consideration was given to the toll revenue that might be possible during a seven year implementation period from 2006 – 2013, as the proposed improvements are being implemented. Since detailed information regarding project phasing and construction impacts was not available, and if it was, would have necessitated extensive additional modeling efforts, a simplified partial revenue approach was adopted. In effect, toll revenues from 2006 – 2013 were estimated for the entire toll network using the off-peak toll rates, which are sub-optimal for the peak periods.

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[9] The 407 Express Toll Route in Toronto, Canada is 100% ETC but allows for autos without transponders to be charged tolls via automatic license plate recognition. A bill is sent to the registered vehicle owner for the toll amount (on a per kilometer basis), along with an administrative charge of approximately $1.75 US.

For revenue estimation purposes, four weekday toll time periods were modeled to span a 15 hour toll period from 6 AM to 9 PM. They include an AM peak period, a PM peak period, a midday period and a two hour evening. The regional model provides AM and PM peak period as well as off peak results in terms of volumes and V/C ratios. These are then used to calculate directional toll rates for these periods, where the off-peak model tolls are applied both the midday and evening periods on weekdays, and all day on weekends.

Traffic volume and flow data from WSDOT was used to determine location and facility specific characteristics for identifying intervals to apply the model-derived toll rates. Specifically, actual traffic volume data was used for two purposes: (1) to develop 24-hour traffic profiles for representative sites on each facility by direction in order to assess current and future location-specific peak and off-peak periods and truck percentage profiles, and (2) to determine weekday to weekend daily adjustment factors for both autos and trucks.

Traffic data was collected at various points that were considered representative of the facility or its sections. Early November traffic data was used as a review system-wide traffic volumes in the Puget Sound Region indicated that November data most closely resembled annual average traffic conditions. Traffic counts for three days, Tuesday, Wednesday and Thursday, were averaged to obtain a weekday averages. Traffic counts for Saturday and Sunday were averaged to determine a weekend average.

The roughly 400 individual model links and their associated toll rates within the regional model were aggregated to 46 analysis segments to make the calculations manageable. The analysis segments were chosen to combine contiguous or homogenous links with similar capacities and traffic characteristics, where inter-link toll rate variation was insignificant. Locations and lengths for the 46 analysis segments are provided in the Appendix information. Combining the 46 analysis segments with three time periods and two directions yields a total of 276 different toll rates that are applied to generate the base annual revenue projections. This number is then doubled by applying the alternate value of time used to help set the projected revenue range.

The 46 analysis segments were further aggregated to 13 sections across the seven facilities for purposes of identifying the location-specific peak period intervals. Table 7 presents the time intervals over which the AM peak, PM peak and off peak period tolls would be in effect for these 13 sections. The above mentioned weekend day factors for total traffic and trucks, as a percentage of the respective weekday factors, is also given. These intervals and percentages were then appropriately applied to all 46 analysis segments.

Table 8 presents the truck percentages that were applied to these 13 sections by daily time periods. The weekend truck percentages were reduced using the factors indicated in Table 7. The truck percentages are a key input to the revenue calculations as the toll modeling outputs apply to all non-HOV vehicles including trucks. Since trucks pay a different toll rate than autos, it is necessary to segregate them out from the regular passenger vehicles.

Table 7
Toll Categories, Time Periods and Weekend Traffic Factors by Facility

Route & Segment (North to South)	*Peak Tolls / Peak Direction*	*Peak Tolls / Reverse Direction*	*Off-Peak Tolls / Both Directions*	*Weekend % of Week-day 15 Hr Toll Period*	
				Total Vehicles	*Trucks Only*
SR-99: Roy St. to 1st Ave S.	NB 6 - 9 AM SB 3 - 7 PM	SB 6 - 9 AM NB 3 - 7 PM	9 AM - 3 PM & 7 - 9 PM	67.8%	13.0%
SR-509: 1st Ave S to I-5	NB 6 - 9 AM SB 3 - 7 PM	SB 6 - 9 AM NB 3 - 7 PM	9 AM - 3 PM & 7 - 9 PM	67.8%	37.2%
I-5: I-405 to Northgate	SB 6 - 9 AM NB 3 - 7 PM	NB 6 - 9 AM SB 3 - 7 PM	9 AM - 3 PM & 7 - 9 PM	88.9%	35.0%
I-5: Northgate to I-90	SB 6 AM - 11 AM NB 2 PM - 7 PM	NB 6 AM - 11 AM SB 2 PM - 7 PM	11 AM - 2 PM 7 - 9 PM	80.7%	45.4%
I-5: I-90 to Southcenter	NB 6 - 9 AM SB 3 - 7 PM	SB 6 - 9 AM NB 3 - 7 PM	9 AM - 3 PM & 7 - 9 PM	75.6%	32.7%
I-5: Southcenter to Pierce Co.	NB 6 - 9 AM SB 3 - 7 PM	SB 6 - 9 AM NB 3 - 7 PM	9 AM - 3 PM & 7 - 9 PM	82.9%	26.2%
SR-520: I-5 to NE 40th St	EB 6 AM - 11 AM WB 2 PM - 7 PM	WB 6 AM - 11 AM EB 2 PM - 7 PM	11 AM - 2 PM 7 - 9 PM	65.1%	35.0%
SR-520: NE 40th St to End	WB 6 - 10 AM EB 3 - 7 PM	EB 6 - 10 AM WB 3 - 7 PM	10 AM - 3 PM & 7 - 9 PM	67.8%	37.2%
I-90: I-5 to I-405	EB 6 AM - 11 AM WB 2 PM - 7 PM	WB 6 AM - 11 AM EB 2 PM - 7 PM	11 AM - 2 PM 7 - 9 PM	59.9%	41.1%
I-90: I-405 to SR-900	WB 6 - 10 AM EB 2 - 7 PM	EB 6 - 10 AM WB 2 - 7 PM	10 AM - 2 PM & 7 - 9 PM	65.1%	39.1%
I-405: I-5 to SR-520	SB 6 - 9 AM NB 3 - 7 PM	NB 6 - 9 AM SB 3 - 7 PM	9 AM - 3 PM & 7 - 9 PM	79.9%	35.9%
I-405: SR-520 to Southcenter	SB 6 AM - 11 AM NB 2 PM - 7 PM	NB 6 AM - 11 AM SB 2 PM - 7 PM	11 AM - 2 PM 7 - 9 PM	78.0%	37.4%
SR-167: I-405 to Pierce Co.	NB 6 - 10 AM SB 2 - 7 PM	SB 6 - 10 AM NB 2 - 7 PM	10 AM - 2 PM & 7 - 9 PM	80.0%	27.4%

Table 8
Toll Time Periods and Truck Percentages

Route & Segment (North to South)	AM Peak Intervals			Midday Intervals					PM Peak Intervals		Evening	Off-Peak
	6 - 9 AM	6 - 10 AM	6 - 11 AM	9 AM - 2 PM	9 AM - 3 PM	10 AM - 2 PM	10 AM - 3 PM	11 AM - 2 PM	2 PM - 7 PM	3 PM - 7 PM	7 - 9 PM	(Midday+ Evening)
SR-99: Roy St. to 1st Ave S.	3.2%				5.4%					2.7%	1.8%	4.8%
SR-509: 1st Ave S to I-5	3.2%				5.4%					2.7%	1.8%	4.8%
I-5: I-405 to Northgate	5.7%				9.2%					4.5%	5.4%	10.5%
I-5: Northgate to I-90			10.4%					12.6%	7.7%		6.9%	15.9%
I-5: I-90 to Southcenter	6.5%				9.1%					4.4%	4.9%	10.1%
I-5: Southcenter to Pierce Co.	7.7%				9.9%					5.6%	5.2%	10.9%
SR-520: I-5 to NE 40th St			5.7%					7.4%	4.7%		2.9%	8.8%
SR-520: NE 40th St to End		5.2%					7.3%			4.2%	2.8%	8.1%
I-90: I-5 to I-405			3.5%					5.3%	3.0%		2.4%	6.4%
I-90: I-405 to SR-900		6.8%				13.6%			6.9%		7.3%	15.8%
I-405: I-5 to SR-520	5.1%				6.5%					3.2%	3.1%	7.2%
I-405: SR-520 to Southcenter			7.5%					9.3%	5.2%		4.2%	11.1%
SR-167: I-405 to Pierce Co.		9.2%				12.2%			5.4%		4.4%	13.6%

As previously described, the values of time used to compute the spectrum of toll rates in cents per mile ranges from one-third (low) to one-half (base) of the annual wage rate for King County. In year 2000 dollars, the average wage rate was $23.66, resulting in a low value of time of $7.89 and a base value of time of $11.83. These amounts are escalated to year of collection dollars using the State of Washington's forecast for the Implicit Price Deflator for personal consumption. The resulting spectrum of toll rates, expressed as minimums, maximums, and weighted averages by facility and time period, in inflated (year of collection) dollars is given in Table 9 for the base value of time. The same toll rate spectrum for the low value of time is presented in Table 10. Additional toll rate tables for 2014 expressed in constant 2000 dollars as well as for 2030 in constant 2000 and inflated dollars are provided in the Appendix for both values of time.

Table 9
Spectrum of Optimal Toll Rates for 2014 in Inflated Dollars
(Base Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.04	$0.22	$0.11	$0.04	$0.22	$0.11	$0.04	$0.04	$0.04
SR-509	11.8	$0.04	$0.14	$0.09	$0.04	$0.14	$0.09	$0.04	$0.04	$0.04
I-5	43.1	$0.04	$0.33	$0.14	$0.04	$0.21	$0.10	$0.04	$0.05	$0.04
I-405	30.2	$0.04	$0.19	$0.11	$0.04	$0.11	$0.07	$0.04	$0.04	$0.04
SR-167	14.1	$0.04	$0.20	$0.12	$0.04	$0.15	$0.09	$0.04	$0.04	$0.04
I-90	13.3	$0.04	$0.25	$0.13	$0.04	$0.18	$0.08	$0.04	$0.04	$0.04
SR-520	12.8	$0.06	$0.42	$0.19	$0.04	$0.28	$0.12	$0.04	$0.07	$0.05
Network	**131.3**	**$0.04**	**$0.42**	**$0.13**	**$0.04**	**$0.28**	**$0.09**	**$0.04**	**$0.07**	**$0.04**

Note: All amounts in year of collection dollars

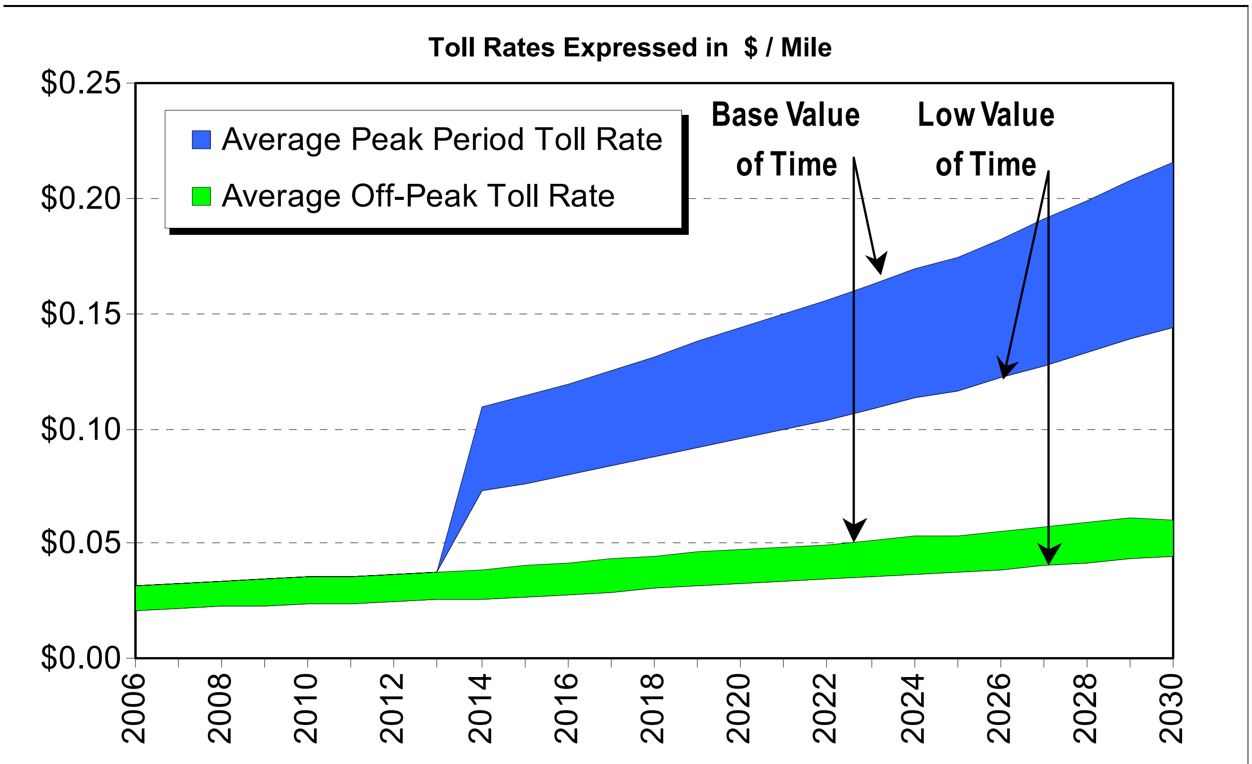
Table 10
Spectrum of Optimal Toll Rates for 2014 in Inflated Dollars
(Low Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.03	$0.15	$0.07	$0.03	$0.15	$0.07	$0.03	$0.03	$0.03
SR-509	11.8	$0.03	$0.09	$0.06	$0.03	$0.09	$0.06	$0.03	$0.03	$0.03
I-5	43.1	$0.03	$0.22	$0.09	$0.03	$0.14	$0.06	$0.03	$0.03	$0.03
I-405	30.2	$0.03	$0.12	$0.08	$0.03	$0.07	$0.05	$0.03	$0.03	$0.03
SR-167	14.1	$0.03	$0.13	$0.08	$0.03	$0.10	$0.06	$0.03	$0.03	$0.03
I-90	13.3	$0.03	$0.17	$0.09	$0.03	$0.12	$0.05	$0.03	$0.03	$0.03
SR-520	12.8	$0.04	$0.28	$0.13	$0.03	$0.19	$0.08	$0.03	$0.05	$0.03
Network	**131.3**	**$0.03**	**$0.28**	**$0.09**	**$0.03**	**$0.19**	**$0.06**	**$0.03**	**$0.05**	**$0.03**

Note: All amounts in year of collection dollars

Figure 7 graphically depicts the system-wide, weighted average peak and off-peak toll rates in inflated dollars over time. In this case, the AM and PM toll rates of Table 9 and Table 10 have been combined, and the bandwidth represents the range of average tolls created by the two values of time considered. Off peak rates are shown beginning in 2006 (they would apply to all periods through 2013), and peak period differentiation is introduced in 2014.

Figure 7
Average Peak Period and Off-Peak Toll Rate Ranges Over Time



In accordance with industry practice, truck toll rates were assumed to be a multiplier of the auto toll, typically ranging from 2× to 4× based upon the number of axles (2, 3, and 4+). Since truck types and sizes vary widely, it was assumed that the average truck corresponded to an auto toll multiplier of 3×. For calculation purposes, the 3× factor was used to generate the high end of the estimated revenue range, and a more conservative 2× factor was used for the low end.

Note that the optimal toll rates would increase over time for two reasons:

1. Growth in traffic demand will necessitate an increasingly higher optimal toll in order to elicit the appropriate travel behavior and diversion to maintain an economically efficient traffic flow; and

2. Over time, general inflation will increase the average wage rate, and thus the value of time, the latter of which drives the calculation of the optimal toll rate.

The results herein assume that the posted toll rates per mile are maintained at their optimal toll levels through annual increases for both inflation and rising demand. Clearly, the operating objectives of the toll facility and the need to manage against congestion will need to be well explained, as imposing annual toll increases may be met with public resistance, let alone the fact that on some occasions, an increase in excess of inflation would be necessary.

The downside risk is that failure to increase the optimal toll rates for either of these two effects could lead to the occurrence or recurrence of congestion on the regional toll network, which could likely reduce person-throughput, and by inefficiently wasting the time of those caught in congestion, negate part of the reason why tolls are imposed in the first place.

Regional Toll Revenue Projections

The traffic projections from the regional model were converted to weekday and weekend day vehicle miles traveled (VMT) by segment and travel direction for the toll periods identified in Table 7. The respective model estimated optimal toll rates were then applied to these VMT data, with the noted adjustments for truck percentages and ETC non-participation/evasion loss, to develop the revenue estimates.

As discussed in detail elsewhere herein, a range of revenue that might be possible with the assumed regional toll network and the economically efficient toll modeling approach was considered by varying the value of time underlying the optimal toll rate as well as varying the truck toll multiplier and the inclusion of weekend toll revenues.

The resulting annual toll revenue forecast ranges for the assumed regional toll network in both constant and inflated dollars are presented in Table 11 through 2030. Table 12 presents each facility's contribution to the high end of the projected total revenue range for selected years in inflated, year of collection dollars. Table 13 presents the same for the low end revenue projection, also in inflated, year of collection dollars. In either case, the operating objective is minimization of overall network travel times. Revenue maximizing toll rates would yield additional revenue, but also higher social travel time costs.

Table 11
Regional Toll Network Annual Revenue Ranges (Constant & Inflated $)

Year	Constant Year 2000 Dollars		Inflated (Year of Collection) Dollars	
	LOW END	*HIGH END*	*LOW END*	*HIGH END*
	Low Time Value 2x Truck Toll Factor No Weekend Tolls	*Base Time Value 3x Truck Toll Factor Weekend Tolls*	*Low Time Value 2x Truck Toll Factor No Weekend Tolls*	*Base Time Value 3x Truck Toll Factor Weekend Tolls*
2006	$ 56.0 M	$ 81.3 M	$ 62.9 M	$ 91.3 M
2007	$ 57.6 M	$ 83.7 M	$ 66.2 M	$ 96.1 M
2008	$ 59.3 M	$ 86.2 M	$ 69.7 M	$ 101.2 M
2009	$ 61.1 M	$ 88.7 M	$ 73.3 M	$ 106.5 M
2010	$ 62.9 M	$ 91.3 M	$ 77.2 M	$ 112.1 M
2011	$ 64.7 M	$ 94.0 M	$ 81.4 M	$ 118.3 M
2012	$ 66.6 M	$ 96.7 M	$ 86.1 M	$ 125.1 M
2013	$ 68.5 M	$ 99.6 M	$ 91.2 M	$ 132.4 M
2014	$ 184.3 M	$ 334.3 M	$ 252.1 M	$ 457.3 M
2015	$ 187.7 M	$ 340.0 M	$ 264.1 M	$ 478.5 M
2016	$ 191.1 M	$ 345.8 M	$ 276.8 M	$ 500.9 M
2017	$ 194.6 M	$ 351.7 M	$ 290.5 M	$ 525.1 M
2018	$ 198.2 M	$ 357.7 M	$ 305.7 M	$ 551.8 M
2019	$ 201.8 M	$ 363.9 M	$ 322.3 M	$ 581.0 M
2020	$ 205.5 M	$ 370.1 M	$ 340.6 M	$ 613.4 M
2021	$ 209.5 M	$ 376.9 M	$ 355.7 M	$ 640.0 M
2022	$ 213.6 M	$ 383.9 M	$ 371.6 M	$ 667.8 M
2023	$ 217.7 M	$ 390.9 M	$ 388.3 M	$ 697.2 M
2024	$ 222.0 M	$ 398.2 M	$ 406.0 M	$ 728.2 M
2025	$ 226.3 M	$ 405.5 M	$ 424.4 M	$ 760.5 M
2026	$ 230.9 M	$ 413.4 M	$ 444.2 M	$ 795.4 M
2027	$ 235.6 M	$ 421.5 M	$ 465.3 M	$ 832.3 M
2028	$ 240.4 M	$ 429.7 M	$ 487.4 M	$ 871.2 M
2029	$ 245.3 M	$ 438.1 M	$ 510.7 M	$ 912.0 M
2030	$ 250.3 M	$ 446.7 M	$ 535.1 M	$ 954.9 M

Table 12
Annual Revenue by Facility for Selected Years — <u>High End</u> Estimates

Toll Facility	*Toll Distance*	*Year of Collection Dollars in Millions*					
		2006	*2013*	*2014*	*2020*	*2025*	*2030*
SR-99	6.1	$3.1 M	$4.1 M	$14.8 M	$18.9 M	$22.6 M	$27.4 M
SR-509	11.8	$2.7 M	$3.7 M	$20.1 M	$25.8 M	$30.7 M	$37.0 M
I-5	43.1	$41.7 M	$60.2 M	$189.2 M	$251.8 M	$310.5 M	$387.0 M
I-405	30.2	$22.5 M	$33.6 M	$119.0 M	$162.9 M	$205.3 M	$261.6 M
SR-167	14.1	$6.3 M	$8.9 M	$32.5 M	$42.6 M	$51.7 M	$63.2 M
I-90	13.3	$6.4 M	$9.6 M	$41.8 M	$57.0 M	$71.7 M	$92.4 M
SR-520	12.8	$8.6 M	$12.3 M	$40.0 M	$54.4 M	$68.0 M	$86.4 M
Network	**131.3**	**$91.3 M**	**$132.4 M**	**$457.3 M**	**$613.4 M**	**$760.5 M**	**$954.9 M**

Table 13
Annual Revenue by Facility for Selected Years — Low End Estimates

Toll Facility	Toll Distance	Year of Collection Dollars in Millions 2006	2013	2014	2020	2025	2030
SR-99	6.1	$2.3 M	$3.0 M	$8.5 M	$10.9 M	$13.0 M	$15.8 M
SR-509	11.8	$2.0 M	$2.7 M	$11.5 M	$14.8 M	$17.7 M	$21.4 M
I-5	43.1	$28.1 M	$40.6 M	$102.8 M	$137.7 M	$170.5 M	$213.1 M
I-405	30.2	$15.4 M	$23.0 M	$64.4 M	$89.2 M	$113.4 M	$145.6 M
SR-167	14.1	$4.3 M	$6.0 M	$17.9 M	$23.7 M	$28.9 M	$35.5 M
I-90	13.3	$4.7 M	$7.0 M	$24.1 M	$33.0 M	$41.7 M	$53.8 M
SR-520	12.8	$6.2 M	$8.8 M	$23.0 M	$31.4 M	$39.2 M	$49.9 M
Network	**131.3**	**$62.9 M**	**$91.2 M**	**$252.1 M**	**$340.6 M**	**$424.4 M**	**$535.1 M**

Figure 8 shows the contribution share of each toll facility to the overall system-wide revenue projections for 2014 under the high end projection, though the low end distribution differences are negligible. Figure 9 graphically presents the range for total network toll revenue (presented in Table 11) in inflated or year of collection dollars. Additional revenue information by facility expressed in constant 2000 dollars can be found in the Appendix.

Figure 8
2014 Distribution of Regional Toll Revenue by Facility

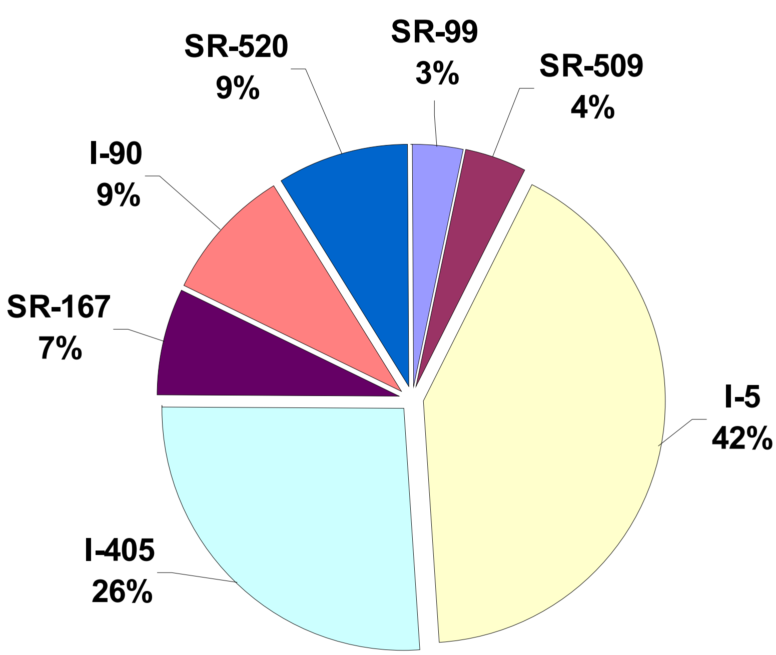
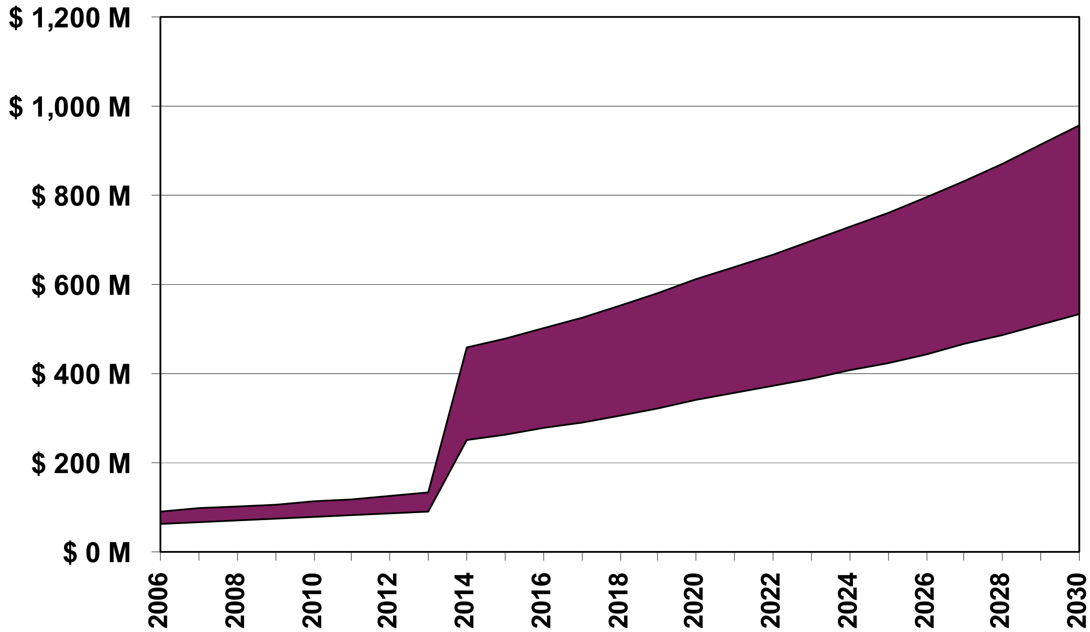


Figure 9
Regional Toll Network Projected Revenue Range in Inflated Dollars



For the "implementation period" from 2006 through 2013, during which the entire regional toll network is assumed to be tolled at the off-peak toll rates, annual revenue is estimated to range from between $63 and 91 million in 2006, growing to between $91 and 132 million by 2013. These numbers need to be carefully considered for two reasons. First, the assumption of sub-optimal tolling of the entire regional network as early as 2006 is a convenient way to roughly gauge revenue collections during a period of toll implementation, but does not realistically convey the likely phased implementation of improvements and concurrent toll collection systems. Second, if optimal tolls were uniformly applied to the regional network during this period, the reality could be that the reduced capacity of pre-improvement facilities undergoing construction would actually lead to higher real toll rates and lower highway traffic volumes than would be observed once the improvement projects were completed. Nonetheless, public resistance may make it impossible to implement the full optimal toll rates prior to completing the various network improvements.

It is interesting to note that the 2013 partial revenue method yields a result that approaches the I-5 contribution to the regional total revenue range (listed in Table 12 and Table 13 for 2014). However, if I-5 were tolled singularly, it is likely that it would generate less revenue than as part of a regional system, although additional modeling work would be required to verify a range for how much. Nonetheless, the simplified revenue estimate for 2006 – 2013 may be a rough proxy for implementing tolls singularly on I-5 from the outset of construction in 2006 through 2013. This might be a reasonable first option, especially for managing congestion on I-5, since although construction will directed elsewhere, construction impacts on I-405, SR-99 and SR-509 would definitely cause diversion to I-5 if it were not tolled to manage congestion. Growth in the projected revenue reflects both higher demand levels over time, which puts upward pressure on the optimal toll rates, and a rising value of time that follows wage inflation.

Typical Toll Costs for Representative Trips

Table 14 presents the typical user toll costs for a range of representative highway trips, as assessed from the base value of time average toll rates as shown in Table 9. Toll costs are shown for the PM peak, AM peak and off-peak time periods. In some cases for trips over 10 miles, multiple routings are presented with their respective costs.

Table 14
2014 Toll Costs for Representative Highway Trips

Representative Trips	Route	Toll Distance by Facility (miles)	Total Toll Distance (miles)	PM Peak Period Trip Toll Cost*	AM Peak Period Trip Toll Cost*	Off-Peak Period Trip Toll Cost*
Less Than 5 Miles						
West Seattle to South Lake Union	I-5 between W. Seattle Bridge & Mercer St.	3.7	3.7	$0.50	$0.36	$0.15
	SR-99 (AWV) between W. Seattle Bridge & Roy St.	4.4	4.4	$0.49	$0.48	$0.17
5 to 9.99 Miles						
Northgate to Downtown Seattle	I-5 between Northgate & Olive Way	6.7	6.7	$0.91	$0.65	$0.26
Downtown Bellevue to UW	I-405 between NE 8th & SR-520 SR-520 between I-405 & Montlake	1.0 5.8	6.8	$1.22	$0.76	$0.30
Issaquah to Downtown Bellevue	I-90 between SR-900 & I-405 I-405 between I-90 & NE 8th Street	5.8 2.7	8.6	$1.06	$0.64	$0.33
Burien to Downtown Seattle	SR-509 between SR-518 & 1st Ave. S. Bridge SR-99 (AWV) btw. 1st Ave. S. Bridge & Midtown	5.5 4.1	9.6	$0.94	$0.93	$0.37
Bothell (SR-522 I/C) to Downtown Bellevue	I-405 between SR-522 & NE 8th Street	9.9	9.9	$1.12	$0.68	$0.38
10 to 14.99 Miles						
Issaquah to Kirkland	I-90 between SR-900 & I-405 I-405 between I-90 & SR-520 SR-520 between I-90 & Lake Wash. Blvd	5.8 3.7 0.7	10.3	$1.31	$0.80	$0.40
	I-90 between SR-900 & I-405 I-405 between I-90 & NE 85th Street	5.8 6.8	12.7	$1.53	$0.93	$0.49
Snohomish Co. Line to Downtown Seattle	I-5 between 244th St. SW & Olive Way	11.6	11.6	$1.57	$1.12	$0.45
Issaquah to Downtown Seattle	I-90 between SR-900 & I-5 I-5 between I-90 & James Street	13.3 0.7	14.0	$1.81	$1.11	$0.55
Downtown Seattle to Redmond	I-5 between Olive Way & SR-520 SR-520 between I-5 & SR-202	1.9 12.8	14.7	$2.70	$1.71	$0.66
15 to 19.99 Miles						
Lynnwood to Downtown Seattle	I-5 between SR-524 & Olive Way	15.3	15.3	$2.08	$1.48	$0.60
Renton to UW	I-405 between SR-169 & SR-520 SR-520 between I-405 & Montlake	10.5 5.8	16.3	$2.29	$1.41	$0.67
Lynnwood to Downtown Bellevue	I-5 between SR-524 & I-405 I-405 between I-5 & NE 8th Street	1.1 16.5	17.6	$2.02	$1.24	$0.68
Kent to Kirkland	SR-167 between 228th St. & I-405 I-405 between SR-167 & SR-520 SR-520 between I-405 & Lake Wa. Blvd.	4.9 12.5 0.7	18.1	$2.15	$1.37	$0.71
20 to 24.99 Miles						
Lynnwood to Downtown Bellevue	I-5 between 44th Ave. W & SR-520 SR-520 between I-5 & I-405 I-405 between SR-520 & NE 8th Street	12.3 7.0 1.0	20.4	$3.13	$2.10	$0.84
Kent to Kirkland	SR-167 between 228th Street & I-405 I-405 between SR-167 & NE 85th Street	4.9 15.6	20.5	$2.37	$1.50	$0.80
Federal Way to Downtown Seattle	I-5 between 320th Street & SR-516 (SR-509 Ext) SR-509 between SR-516 & 1st Ave. S. Bridge SR-99 (AWV) between 1st Ave. S. Bridge & Midtown	5.3 11.8 4.1	21.1	$2.21	$1.99	$0.82
	I-5 between 320th St. I/C & James Street	21.5	21.5	$2.91	$2.08	$0.84
Auburn to Downtown Bellevue	SR-167 between SR-18 & I-405 I-405 between SR-167 & NE 8th Street	12.0 11.5	23.5	$2.76	$1.83	$0.91
Greater than 25 Miles						
Renton to Lynnwood	I-405 between SR-169 & I-5 I-5 between I-405 & SR-524	25.9 1.1	27.0	$3.10	$1.89	$1.05
	I-405 between SR-167 & I-5 I-5 between I-405 & SR-524	2.3 27.0	29.3	$3.92	$2.77	$1.15
Everett to Tacoma	I-5 between I-405 & Pierce Co. Line	43.1	43.1	$5.84	$4.17	$1.69
	I-405 between Swamp Creek & Tukwila Interchanges I-5 between I-405 & Pierce County Line	30.2 15.0	45.2	$5.46	$3.52	$1.76

* Reflect vehicle miles traveled (VMT) weighted average toll rates and overall toll costs

Diversion of Trips from Tolled Facilities

Compared with the toll-free case, introduction of optimal tolls on the assumed network of limited access highways in King and South Snohomish Counties will result in the diversion of some vehicle trips away from these facilities during the toll period. These diverted trips fall into several categories:

- Travelers who make the same trip but divert to an alternate, un-priced route, usually another highway or arterial street;
- Travelers who continue to make the same trip on the tolled facility using their private vehicle, but traveling at a different time of day, when there would be a lower toll rate;
- Travelers who continue to make the same trip at the same time of day, but who will now travel in a vehicle that can use toll-free HOV lanes , either in a high occupancy vehicle with three or more occupants or in a bus;
- Travelers who will choose to change their trip behavior, either traveling to a different destination, such as one in a different direction that they can get to without using a tolled highway, or one nearer to their origin so that the shorter distance results in a lower toll charge to get there; and
- Travelers who opt to eliminate trips, either by not traveling at all, or by combining the functions of two or more trips into a single trip.

The average toll period model diversion rates by facility due to optimal pricing are shown in Table 15. As the road improvements and associated tolling is not assumed to be fully implemented prior to 2014, results for 1998 – 2013 reflect simulations of these years' demand levels with the future (2014) toll network and associated improvements. Actual diversions rates vary somewhat by location, time of day and direction of travel for each facility.

Table 15
Average Toll Period Diversion Rates by Facility and Analysis Year

Toll Facility	*Toll Distance*	*Rates of Diversion*						
		1998	*2006*	*2013*	*2014*	*2020*	*2025*	*2030*
SR-99	6.1	-10.8%	-11.3%	-11.7%	-11.8%	-12.1%	-12.4%	-12.7%
SR-509	11.8	-17.3%	-17.4%	-17.4%	-17.4%	-17.4%	-17.4%	-17.5%
I-5	43.1	-16.2%	-17.1%	-17.8%	-17.9%	-18.6%	-19.1%	-19.7%
I-405	30.2	-13.0%	-14.6%	-15.9%	-16.1%	-17.2%	-18.1%	-19.0%
SR-167	14.1	-17.1%	-17.6%	-18.0%	-18.0%	-18.4%	-18.6%	-18.9%
I-90	13.3	-6.4%	-6.4%	-6.4%	-6.4%	-6.4%	-6.4%	-6.4%
SR-520	12.8	-16.2%	-16.8%	-17.3%	-17.4%	-17.8%	-18.2%	-18.5%
Network	**131.3**	**-14.4%**	**-15.3%**	**-16.0%**	**-16.1%**	**-16.8%**	**-17.3%**	**-17.9%**

Note that the diversion percentages shown in Table 15 apply only to non-HOV travel; the actual change in highway traffic volumes would be somewhat less due to a portion of the diverted vehicles converting to 3+ HOVs where they would use the toll-free HOV lanes.

The relatively low diversion rates for I-90 reflect the excess capacity and superior travel conditions of this facility relative to the SR-520 alternative as well as the lack of alternatives for Mercer Island residents. Essentially, I-90 is the preferred choice for cross-lake travel for trips that could reasonably use either I-90 or SR-520. However, modeling results from the Trans-Lake Washington project indicate that the diversion rates for I-90 would double to approximately 13% if additional general purpose capacity were added to SR-520 under the eight lane scenario (six general purpose lanes). Additional capacity on SR-520 tends to balance out the relative travel advantages that I-90 otherwise provides. Moreover, approximately one-quarter of the I-90 bridge traffic between I-5 and I-405 is either to or from Mercer Island. Because travel to or from the island has no other alternative but to use I-90, the diversion rate for these trips is very low.

The regional travel demand model used in this analysis does an adequate job of estimating the overall levels of diversion, but it is less able to provide reasonable estimates of what would become of the diverted vehicles, particularly for diversion to arterial streets. The model is most able to estimate diversions to other routes and other modes, and is least able to estimate diversions to other time periods or eliminations of trips.[10] As a result, the model may overestimate the impact of tolling on adjacent parallel highways and arterial streets, particularly if some of the diverted trips are actually eliminated or shifted to less congested times. Moreover, as the arterial network gets congested, the model's volume-delay function may not sufficiently discourage arterial street use (as an alternative to the tolled highway), which could cause the model to over-estimate toll diversion, and in so doing, underestimate optimal toll rates — both of which would underestimate the revenue yield.

The model processes for determining diversion, interpretation of the resulting diversion rates, and the impacts on the arterial system warrant further research and analysis. Though the model attempts to minimize overall network travel times, it is unclear by how much the arterial street network is affected, as well as what share of diverted trip end up on the arterials. Examining the 2030 traffic forecast with and without tolls indicates that, at least on a daily basis, total vehicle miles traveled on the arterial system would not increase with the presence of tolls on the limited access facilities, and may actually decrease slightly. However, intra-zonal trips are not usually assigned in network modeling, and these trips increase by about 2% when tolls are simulated. Whether or not these short intra-zonal trips actually occur and represent an significant increase in VMT, or are just a model proxy for trips that would otherwise be eliminated except for model's fixed demand constraint is unclear. Nonetheless, there are bound to be individual arterial segments that would undoubtedly be loaded with increased traffic at certain times of day.

[10] The overall network demand remains relatively fixed in the regional model, which may not be a reasonable assumption with implementation of regional tolling.

Toll Revenue Assumptions and Their Likely Effects on Outcomes

Limitations of the regional model when stretched to simulate highway pricing have been discussed. Given the nature of these forecasting methods and the lack of in-depth market research regarding user behavior with tolls, a concerted effort was made to generally use conservative revenue calculation assumptions where possible to avoid producing forecast scenarios that might be considered too optimistic. Below are a list of assumptions and model outcomes categorized as either optimistic/uncertain or conservative. While it is not possible to quantitatively measure the net effects of these, the fact that the conservative assumptions/outcomes considerably outnumber the optimistic/uncertain ones suggests that the resulting toll revenue range presented herein are not overly optimistic.

Optimistic and Uncertain Assumptions/Outcomes

- Though not part of any planned project, an SR-99 limited access extension between the First Avenue South Bridge and Spokane Street was modeled which effectively connects SR-99 with SR-509 to form a better western corridor option to I-5.
- Updates to the future land use assumptions and associated population and employment projections that are inputs to the regional model were not revised. It is conceivable that widespread tolling may eventually impact future residential and business location choices, and even land use patterns, reorganizing the proximity of households to their jobs. It is unclear as to what degree such change might occur, and moreover, redistribution of land use patterns within King County is less likely due to the balancing effects of tolling most all of the major highway facilities.
- It has been assumed that the revenue loss due to electronic toll collection non-participation or evasion would be 5% system-wide. Unfortunately, there is no comparable situation and associated empirical data for testing this hypothesis. Existing ETC facilities either have a cash payment option, an adjacent parallel roadway, or do not represent conversion to tolls of an existing facility. Moreover, the widespread implementation assumed in this case would tend to make ETC participation almost non-avoidable. It should also be reiterated that no operating nor transactions costs have been included in the revenue estimates.
- The assumption that toll rates will rise with inflation and growing demand in a timely manner to maintain their optimal levels may not necessarily occur because of administrative, legal or other operational constraints not anticipated in this report.

Conservative Assumptions/Outcomes

- The revenue projections assume that tolls are not collected from 9 PM to 6 AM. While most of this time period has relatively low volumes of traffic, there are times when conditions may warrant tolling certain night hours, which could generate some additional revenue.
- At times on weekends, traffic congestion can approach and even surpass weekday levels, and the optimal toll rates would move in the same direction. However, rather than attempting to identify and model these periods, it was conservatively assumed that on average, weekend conditions would mirror those of the weekday off-peak periods. Moreover, the low end of the revenue range excludes weekend tolls altogether.

- The regional model uses the Bureau of Public Road's volume-delay function with an exponential coefficient that may overstate the diversion impacts, particularly to the arterial street network. The same BPR volume-delay function specification is used for both freeways and arterials, despite the fact that they operate differently as demand increases. While these inputs are being reviewed and updated as part of the PSRC model update process, in the interim, potentially overstated diversion may result in understated toll rates and toll revenue.[11]
- The values of time used to convert the model-derived toll time costs to dollars per mile range from conservative at one-third the average wage rate to reasonable at one-half the average wage rate. However, user's willingness to pay can increase significantly above these values on the margin, especially during congested peak periods. However, no attempt was made to model these potential peak period effects.
- A case can be made that real wage rates, and thus the imputed real values of time, show positive growth. Put another way, productivity increases are projected to cause nominal wage rates, and thus values of time, to grow faster than projected general inflation rates. This would then lead to increasingly higher tolls over time than those used herein. However, real wage rates/values of time were assumed to be constant, with nominal values matching projected inflation.
- The model output V/C ratios, from which the optimal toll rates are computed, were capped at 1.25, which results in a maximum toll rate per mile of 29¢ in year 2000 dollars. In a few cases, the model results indicated higher V/C ratios, which would have yielded exponentially higher toll rates on certain segments, and thus more optimistic revenue foreasts.
- The regional model was applied with the 2030 transit and HOV networks for both the base year (1998) and future year (2030) model runs. For years prior to 2030, this overstates the true transit levels of service available, and thus may have the effect of overstating transit use, and thus, understating roadway demand, toll rates, and resulting revenue.
- The economic efficiency toll modeling approach yields toll rates that seek to maximize total net social benefits of using the network, particularly that of minimizing overall network travel time. These toll rates are less than those that would maximize revenue, though the latter cannot be readily estimated with existing tools. Nonetheless, to the extent that demand becomes more elastic over time, the difference between the model-derived economically efficient tolls and those that would maximize revenue may decrease.

Annual Toll Revenue Purchasing Power

A revenue projection raises the question of how much will the annual cash flow buy, in terms of capital investment, via bond debt financing. Several factors would influence this, including the duration of construction; prevailing interest rates; debt structure, duration and issuance costs; projected rate of revenue growth; and required debt service coverage, among others. Moreover,

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[11] The 2000 Highway Capacity Manual recommends coefficients for the BPR volume-delay function by facility type that generally exceed the value of 4 used in the regional model. This results in travel time delay costs that rise faster with increasing volume, especially on arterial streets, which would tend to make arterials less attractive alternatives with tolls on the highways.

the range of investments being considered, their interactive effects on toll revenue, and their combined duration of construction further complicates matters. It is unreasonable to assume that toll revenues could be used to finance a large portion of initial construction costs, as toll revenue bonds typically require commencement of debt service funded from toll revenues (as opposed to capitalized as part of the project cost for which borrowing is employed) no more than a couple of years after issuance.

Essentially, a realistic assessment of the financial capacity of the toll revenue estimates herein would require detailed information regarding the timing of other revenue sources, proposed debt instruments, construction costs and phasing, toll collection implementation and technologies, and a host of other factors (e.g., debt service coverage requirements, issuance costs, debt terms and duration, etc.), which would then serve as input to a detailed financial analysis of regional highway investments.

In the absence of such a financial analysis, all that can be considered is the somewhat unrealistic case where toll revenues would be immediately available to begin debt service payments. Under this scenario with prevailing interest rates and other reasonable assumptions, each $1 million of annual toll revenue, net of any operating costs, could leverage approximately $9-11 million of capital investment via the sale of 25 year municipal revenue bonds or similar debt instruments. To the extent that bond proceeds are brought forward, delaying the commencement of toll revenues for repayment, the net proceeds will decrease.

RELATED STUDIES AND TOLL FACILITY INFORMATION

Comparison with the County Executives Revenue Forecasts

Recognizing that implementing the needed regional transportation improvements will require new local revenue sources, the County Executives of King, Snohomish, and Pierce Counties proposed a Regional Transportation Improvement District (RTID) mechanism for generating local revenue to pay at least of portion of the costs for a list of regional projects. This plan was presented to their respective county councils on May 1, 2002, and is expected to evolve into a ballot measure to take forward to the voters as early as November 2002. For each project, specific revenue sources and yields for the 10-year period from FY 2003-2012 were estimated. Put simply, the package indicated how much funding (for which projects) the regional mechanism would provide under various levy rate assumptions. Five types of revenue were included as funding sources in the county executives' package:

- Sales tax;
- Vehicle licensing fees;
- Local option motor vehicle excise tax;
- Unused transit tax capacity (King County only); and
- Tolls

It is notable that there is basic parity between each county's revenue projections and the sum of the project costs on that county's list. It appears that the county-specific forecasts for all of these revenue sources, except for tolls, were developed in conjunction with WSDOT, which relied on information from the Departments of Licensing and Revenue, and were calculated according to well-established projection methodologies.

The forecasts for toll revenues contained in the County Executives' package, however, are qualitatively different from the forecasts for the other revenue sources. The time frame and resources available for developing toll forecasts were insufficient to employ a rigorous forecasting methodology including an examination of the effects of tolling on driver behavior. As such, the toll revenue forecasts contained in the County Executives' package are very preliminary. Nonetheless, it is helpful to understand how they were developed in order to explain notable differences between the toll revenue figures in the County Executives' package and the regional toll revenue forecasts allocated by facility presented herein.

In the County Executives' package, tolls are only used to help fund three mega-projects in King County: the Alaskan Way Viaduct replacement, Translake Washington (SR-520) improvements, and I 405 widening and improvements. Table 16 presents the County Executives' expected contributions from tolls for fiscal years 2003-2012 by each of the three mega-projects.

Table 16
County Executives' Proposed Plan 10-Year Toll Revenue Projections
FY 2003-2012

Project	Toll Revenue (10 Years)	Regional Contribution Assumed	Total	% of Regional Funding from Tolls
Alaskan Way Viaduct	$500 M	$1.5 B	$2 B	25%
405 Tukwila to Woodinville	$450 M	$1.0 B	$1.45 B	31%
SR 520 Translake	$600 M	$800 M	$1.4 B	43%

For I-405 and SR-520, the method used to come up with toll revenues for the 2003-2012 period was relatively simple.[12] Traffic volumes from WSDOT's *2000 Annual Traffic Report* were compiled for a selected "midpoint" location on each facility. Estimated traffic growth rates were then applied for each year through 2012. Toll revenue was then simply estimated as a flat $1.00 toll for the projected annual traffic volume crossing at these identified locations. In essence, toll revenues were estimated by multiplying the projected traffic at a single point for all times of day and days of the week by $1.00. The totals for each year were then summed up to arrive at ten-year estimates of toll yields by facility. The Alaskan Way Viaduct toll revenue projection of $500 million appears to be more speculative. This figure is well in excess of 10 years of annual traffic all paying a $1.00 toll, which would likely equate to something closer to $300 million.

While this methodology has the advantage of being easy to compute and understand, it has significant shortcomings. Among its disadvantages — relative to the regional toll modeling approach of this study — are that tolls are assumed to be collected on all trips, regardless of time of day or day of the week This assumption may not be realistic from a public acceptance standpoint, and it is undesirable from the perspective of trying to manage demand by pricing according to prevailing conditions. In some cases, charging the same toll at all times may tend to overstate the revenue potential, depending on the toll rate assumed, because it ignores the fact that diversion would occur and vary by time of day and trip purpose.

At the same time, this approach could also underestimate the revenue potential. The true revenue potential of tolling cannot be discerned by forecasting on the basis of single cordon lines—particularly on long corridors like I-405. Such a method would tend to miss a significant number of facility users that do not cross that point. For instance, this approach would not capture I-405 trips that begin and end without crossing the Bellevue cordon line, as would a trip from Kirkland to Woodinville.

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[12] This method was not specified in the transmission of the County Executives' package to the councils. Rather, it appears that it was used by staff to produce order of magnitude toll revenue estimates.

In addition, the County Executives approach does not account for the distance traveled; a person traveling the length of I-405, for instance, would pay no more than a person using this highway to from downtown Bellevue to Kirkland. Similarly, it does not distinguish between passenger vehicles and trucks. Because trucks tend to reap greater benefits from time savings while also causing more damage to the roadway, it may be desirable to charge these vehicles higher tolls.

Also, this approach does not account for the toll elasticity of demand, that is changes in travel behavior — diversion to alternate routes, trip consolidation, mode changes, and/or trip elimination — due to changes in the cost (price) of travel, nor the potential effects of inflation.

Context of Other Toll Modeling Efforts

Concurrent with this study of the feasibility and revenue potential of regional tolling, individual project planning and engineering work for several of the facilities in the proposed regional toll network is also being conducted by WSDOT and various consultants. Specifically, the SR-520 Translake, I-405, and Alaskan Way Viaduct corridor are in various stages of the Environmental Impact Statement (EIS) process, in which tolling options are being considered.

For the Alaskan Way Viaduct, a Draft Toll Feasibility Study has been conducted and the Final is expected shortly. The preliminary results of this work indicate that while tolling is feasible, the demand characteristics of this relatively short roadway as a stand-alone facility, combined with the availability of un-priced alternative routes, limit the revenue potential to an amount much less than that anticipated by the County Executives' plan. When leveraged with bonding, the Viaduct's toll revenues are likely to cover well less than 10% of the project cost.

Toll revenue projections for an independent SR-520 Translake Washington project have not yet been completed. However, preliminary modeling results suggest that the volumes and congestion levels for the six-lane alternative are expected to be similar to those projected for the SR-520 component of this study's regional toll modeling effort, and thus, so too would this similarity extend to toll revenue. This would suggest that the revenue potential of SR-520 may be more independent of the existence of region-wide tolling than that of the other facilities that do not serve such a captive market.

Modeling has also been done for the I-405 widening project EIS, though the toll modeling work is preliminary, and has to-date focused primarily on high occupancy toll (HOT) and managed lanes concepts — whereby single occupant vehicles (SOVs) are allowed to purchase excess managed lane capacity — as opposed to the tolling of all lanes of the facility. Formal revenue estimates for the modeling work to-date have not been produced.

Demand Effects of Removing Tolls on Washington State Toll Bridges

To put into perspective the roughly 15% toll diversion to other routes expected for the Alaskan Way Viaduct or its replacement facility, traffic data was analyzed before and after removal of tolls on the two most recent such facilities in Washington State.

SR-520 Floating Bridge Experience

The Governor Albert Rosellini Evergreen Point Floating Bridge (SR-520) opened in August 1963 with a $0.35 toll each way. The toll rate was set to pay debt service costs for construction bonds. In today's dollars, the $0.35 toll in each direction is equivalent to $1.70. With projected inflation, this corresponds to $2.30 in 2014, the assumed year of implementation for regional tolling as modeled herein.

The SR-520 bridge toll — still at $0.35 per direction — was removed in June 1979. At the time of removal, the real cost of the toll had declined considerably since the bridge opening to about $0.85 in today's dollars, or $1.14 in year 2014 dollars.

In 1978, the last full year of toll operations, AADT numbered 60,452 vehicles, versus 56,752 on the un-priced parallel I-90 Floating Bridge. By 1980, AADT on SR-520 had jumped 19.3% to 72,139 while traffic on I-90 fell by 7.9% to 52,283 for no other apparent reason than SR-520 becoming more attractive. These results suggest that toll diversion on SR-520 was approximately 16.2%, with over one-third of the toll-inhibited vehicle trips diverted to I-90, and the remainder either north around the lake or not at all.

Hood Canal Bridge Experience

The $2.00 toll on the Hood Canal Bridge was removed on August 29, 1985. In 1984, annual average daily traffic (AADT) was 5,982 vehicles with the toll. In 1986, AADT jumped 38% to 8,253 vehicles in the first full year without the toll. This seems to indicate that in the year before the toll was eliminated, it was causing a diversion of 27.5% of would-be vehicle trips to either be made using alternative routes, or more likely in this case, to not be made at all.

Toll Rate and Revenue Information for Selected North American Toll Facilities

The following tables provide some comparable information for 13 selected toll roads or systems of toll roads in the U.S. and Canada. While the list of facilities is by no means comprehensive, it does provide some context for the implementation of tolls in the Puget Sound Region. Table 17 identifies some of the general characteristics of these facilities, including length, year of opening, type and configuration, payment methods, etc. Table 18 presents pricing, revenue and utilization information for the same 13 facilities. Some of the toll road characteristics have been simplified for presentation purposes, with the intent of providing summary-level comparisons. Toll rates, where presented as ranges, may arise from variable pricing by time of day / demand levels / ETC discounts, may be due to fixed toll rates charged over segments with different lengths, or some combination of these factors. Revenue for different facilities can vary greatly based on a number of factors including the operating objective, length and configuration of the facility, toll rate, and the travel market/demand levels served.

Table 17
General Characteristics of Selected North American Toll Facilities

Toll Facility & Location	Year Opened	Principal Operating Objective	Overall Length (miles)	Type / Configuration	Access	Open to Trucks?	Payment Methods (ETC = electronic toll collection)	Toll Parameters / Unit
SR-91 Orange Co., CA	1995	Revenue maximization	10	Located in the median of the SR-91 freeway	End-points only	No	100% ETC	Variable rate for entire facility distance
I-15 FasTrak San Diego, CA	1996	Throughput target	8	Two-lane, reversible facility in the median of I-15.	End-points only	No	100% ETC	Variable rate for entire facility distance
Dulles Greenway Dulles, VA	1995	Revenue maximization	14	Privately toll road. Four lanes with reversible options.	Multiple access / exit points	Yes	ETC, credit card & cash (no coins)	Flat rate between exits and/or plazas
SR-267 Dulles Toll Road Dulles, VA	1984	Revenue target (retirement of debt, O&M costs)	14	8 lane (4 lanes in each direction) limited access highway	Multiple access / exit points	Yes	ETC & cash	Flat rate between exits and/or plazas
Harris County Toll Roads Houston TX	1987	Revenue target (retirement of debt, O&M costs)	83	Limited access tolled ring road	Multiple access / exit points	Yes	ETC & cash	Flat rate between exits and/or plazas
New Jersey Turnpike NJ	1951	Revenue target (retirement of debt, O&M costs)	118	Dual toll facilities; trucks prohibited from using one of the two roads.	Multiple access / exit points	Yes[1]	ETC, cash & tokens	Flat rate between exits and/or plazas
407 Express Toll Route (ETR) Toronto, Canada	1997	Revenue maximization	68	Limited access toll road	Multiple access / exit points	Yes	100% ETC	Per kilometer rate between exits and/or plazas
E470 Denver, CO	1998	Revenue target (retirement of debt, O&M costs)	46	Limited access toll road. Partial ring road	Multiple access / exit points	Yes	ETC & cash	Flat rate between exits and/or plazas
Homestead Extension (HEFT) FL	1974	Revenue target (retirement of debt, O&M costs)	47	Limited access toll road	Multiple access / exit points	Yes	ETC & cash	Flat rate between exits and/or plazas
Polk Parkway FL	1998	Revenue target (retirement of debt, O&M costs)	25	Limited access toll road	Multiple access / exit points	Yes	ETC & cash	Flat rate between exits and/or plazas
Southern Connector, Greenville, SC	2001	Revenue target (retirement of debt, O&M costs)	16	Limited access toll road	Multiple access / exit points	Yes	ETC & cash	Flat rate between exits and/or plazas
SR-73 San Joaquin Toll Road Orange Co., CA	1996	Revenue target (retirement of debt, O&M costs)	15	Limited access toll road	Multiple access / exit points	Yes	ETC & cash	Variable rates between exits and/or plazas
SR-261, SR-241 & SR-133 Foothill & Eastern Toll Roads Orange Co., CA	1993–1999	Revenue target (retirement of debt, O&M costs)	36	Limited access toll road	Multiple access / exit points	Yes	ETC & cash	Flat rates between exits and/or plazas

[1] Trucks are excluded from one of the two roadways in this dual roadway configuration

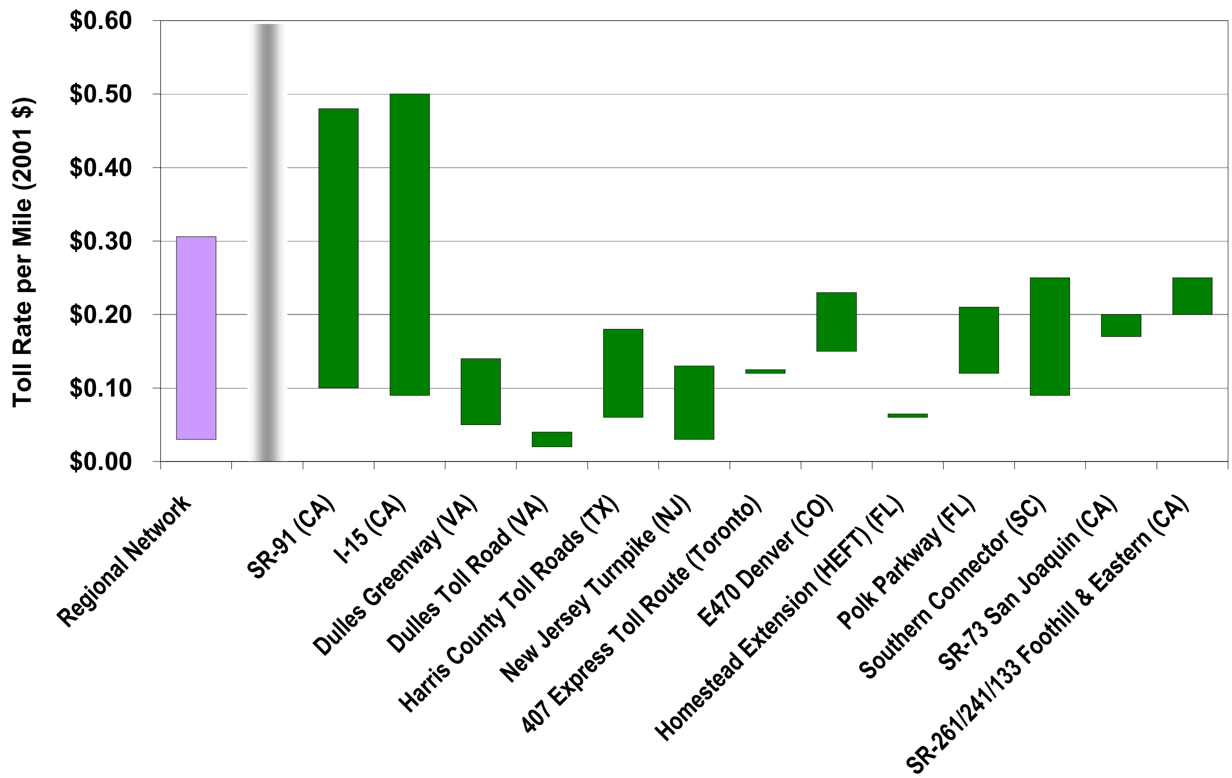
Table 18
Pricing, Revenue & Utilization for Selected North American Toll Facilities

Toll Facility & Location	Toll Rates / Mile	Variable Tolls (by Time of Day or Demand)?	Range of Trip Cost (varies with toll rate & distance)	HOV Discount?	Annual Toll Revenue	Average Revenue / Mile	Annual Vehicle Trips	Annual Toll Transactions	Revenue/ Vehicle Trip	Revenue / Transaction
SR-91 Orange Co., CA	$0.10 – $0.48	Yes	$1.00 – $4.75	Yes	$21.3 M (2000)	$2.1 M	7.7 M	7.7 M	$2.77	$2.77
I-15 FasTrak San Diego, CA	$0.09 – $0.50	Yes	$0.75 – $4.00 (up to $8.00 w/ incident)	Free	$1.2 M (2002)	$0.15 M	4.4 M	N/A	$0.27	N/A
Dulles Greenway Dulles, VA	$0.05 – $0.14	Yes	$0.50 – $2.00	No	$19.8 M (2000)	$1.4 M	14.4 M	N/A	$1.38	N/A
SR-267 Dulles Toll Road Dulles, VA	$0.02 – $0.04[3]	No	$0.25 – $0.50	Free	$31.2 M (1996)	$2.2 M	N/A	96.2 M	N/A	$0.32
Harris County Toll Roads Houston TX	$0.06 – 0.18[3]	No	$0.25 – $1.00 ($1.50 - 2.00 for Ship Bridge)	No	$217.8 M (2001)	$1.7 M	140 M	N/A	$1.02	N/A
New Jersey Turnpike NJ	$0.03 – 0.13	Yes[1]	$0.45 – $5.5	No	$392 M (2000)	$3.3 M	N/A	214.9 M	N/A	$1.82
407 Express Toll Route (ETR) Toronto, Canada	$0.12[2]	No	$0.46 – $8.25[2]	No	$244 M (2001)	$3.6 M	86.1 M	N/A	$2.83	N/A
E470 Denver, CO	$0.15 – $0.23[3]	No	$0.50 – $5.75	No	$23.2 M (2000)	$0.5 M	N/A	23.4 M	N/A	$0.99
Homestead Extension (HEFT) FL	$0.06	No	$0.25 – $2.75	No	$63.5 M (2001)	$1.4 M	N/A	144 M	N/A	$0.56
Polk Parkway FL	$0.12 – $0.21[3]	No	$0.24 – $3.00	No	$10.2 M (2001)	$0.5 M	N/A	12.8 M	N/A	$0.80
Southern Connector, Greenville, SC	$0.09 – $0.25[3]	No	$0.50 – $1.50	No	$2.6 M (2001)	$0.2 M	3.5 M	N/A	$0.75	N/A
SR-73 San Joaquin Toll Road Orange Co., CA	$0.17 – $0.20	Yes[1]	$0.50 – $3.00	No	$60.7 M (2001)	$4.0M	N/A	28.4 M	N/A	$2.14
SR-261, SR-241 & SR-133 Foothill & Eastern Toll Roads Orange Co., CA	$0.20 – $0.25[3]	No	$0.50 – $4.50	No	$83.5 M (2001)	$1.5M	N/A	60.9 M	N/A	$1.37

[1] Varies only for electronic toll collection [2] in U.S. dollars / mile [3] Variation due only to fixed tolls over different segment lengths

Figure 10 presents a comparison of the range of toll rates for the selected toll facilities to those develop for the regional network using a base value of time that is half the average wage. Unlike most facilities noted here, the regional network assumes toll rates that vary by time of day and by congestion levels. Furthermore, the facilities listed here have varying operating objectives, such as covering debt service or O&M costs, which tend to result in toll rates or time of day toll structures that are sub-optimal from the standpoint of revenue maximization or minimization of overall network travel times. Any range in the toll rate per mile for these facilities is typically a result of the unit distance tolled rather than intentional variation, with the exceptions of SR-91 and I-15. At the time of writing, SR-91's operating objective and toll structure are focused on revenue maximization.

Figure 10
Comparison of the Regional Network Toll Range with Selected North American Toll Road Toll Ranges in 2001 $



NEXT STEPS

The focus of this study has been to identify the approximate range of annual revenue from tolling by examining the implementation of highway pricing region-wide. The regional modeling approach used employs the best currently available tools, and strikes a balance between technical methods and resource constraints. Optimal toll rate estimates and revenue forecasts resulting from this process represent initial or planning stage results, and are intended to inform decision-makers considering a myriad of infrastructure investments and possible funding sources. This fact suggests a number of possible next steps — from an analysis standpoint — that could be undertaken assuming that the preliminary revenue results, not to mention public interest, look sufficiently promising to warrant further consideration of region-wide or facility specific tolling.

First, additional toll research, modeling and revenue estimation work should be considered, ranging from additional modeling sensitivity testing and assumptions refinement to a much more involved process yielding "investment grade" traffic and toll revenue forecasts. Possible future work elements are described below.

Second, as part of the refinement of the traffic and revenue forecasts, consideration needs to be given to the operating objectives of tolling. In other words, is the objective to maximize revenue by creating relatively substantial time savings benefits for those most willing to pay, or is it to generate some revenue while maximizing network travel benefits by minimizing the collective travel time of all users. This issue is further discussed below.

Third, much more attention should be directed to the technological and policy considerations of toll collection, especially with consideration of a regional toll network. This effort should include an in-depth look at the toll collection capital investments, technology application, and ongoing operations, maintenance and administration costs. Ideally, this work would be done independently of any toll modeling and revenue refinement, but with shared assumptions regarding operations, especially if operating assumptions are altered in such as way as to potentially affect the revenue projections. As an element of the design process, this effort should also be subjected to the WSDOT Cost Estimation and Validation Process (CEVP).

Fourth, additional research and legal analysis would need to be undertaken to identify the Federal policies and State laws that would need to enacted or amended to facilitate regional tolling, particularly for existing interstate facilities and facilities not previously contemplated for tolling under existing State law.

Finally, the breadth and complexity of the capital projects that regional toll revenues may be required to support would necessitate a systematic financial analysis in order to identify the true leveraging capacity of annual toll revenues. The inability to simply suggest that each million dollars of toll revenue supports some multiplier of capital investment through bonding is primarily a function of timing and scale. Anticipating that construction of several mega-projects requires more than several years, and that toll revenues would not likely be fully available for debt service until the majority of network improvements are complete, may lower the financial capacity of the toll revenue stream and require other funding sources and financial tools to bring more funding "up front" with construction expenditures. The financial analysis would also need to include the toll collection capital investments as part of the overall project costs, and the ongoing operations costs would need to be subtracted from the annual toll revenue stream in order to identify the net revenues available for debt service.

Revenue Validation and Investment Grade Toll Revenue Forecasts

Assuming that toll revenues look promising and are intended to serve as a primary source of funds from which to borrow against and cover debt service costs (e.g., the sale of revenue bonds), then the successful issuance of debt will likely require completion of a more thorough, "investment grade" toll traffic and revenue forecast study.

What exactly defines "investment grade" toll traffic and revenue forecasts? In a simplistic sense, the answer is whatever revenue forecast assumptions, methods, and review procedures that are sufficiently conservative to instill the confidence of the bond rating agencies and financial markets.

Specifically, a minimum "investment grade" rating from one or more rating agencies is necessary to achieve reasonable financing terms and cost-effectively sell toll revenue bonds.[13] Rating agencies such as Standard and Poor, Moodys and Fitch evaluate the revenue sources that would be dedicated to the repayment of bonds in order to rate the risk associated with a particular issuance. A proposed issuance that receives a rating is considered investment grade, and the better the rating, the more marketable the securities are and the lower the interest rate paid by the borrower, all else equal. Bonds that backed by revenue sources with sufficient uncertainty that they do not to get rated are known as sub-investment grade or "junk" bonds. Such bonds can be difficult to market, and result in very high interest costs as investors demand a premium return commensurate with the risks of default.

In order to obtain an investment grade rating, an independent third party must prepare a detailed traffic and revenue study that addresses all of the pertinent issues related to the toll revenue, including the elasticity of demand, demographic inputs (an independent view of this separate from the MPO), toll rates, operations and maintenance costs, etc.[14] In addition, investment grade forecasts tend to be distinguished from preliminary or planning grade results by their more rigorous and critical deliberation of assumptions, methods and review procedures at all stages. Finally, they typically result in a very thorough and professional report combined and in-person meeting with the rating agencies.

The actual assumptions, methods and review procedures for an investment grade study are not proscribed — in fact, they can vary across projects and be subject to considerable debate — rather it is the thorough consideration of risk variation, examination of inputs, validation tests, high standards of quality, and independent review at every step of the process that tend to characterize investment grade results. It should also be noted that investment grade results involve much more time consuming and costly efforts than do the initial planning level

[13] Financial assistance via the federal Transportation Infrastructure Finance and Innovation Act (TIFIA) also requires investment grade traffic and revenue forecasts.

[14] In the U.S. tax-exempt bond market, there are currently only a few firms that the rating agencies are willing to rely upon for these forecasts

forecasts. However, if the decision has been made to rely on toll revenues for a significant share of project funding, investment grade forecasts are warranted and will pay for themselves by conveying and reducing risks as well as facilitating and lowering the cost of project financing.

While the discussion of planning versus investment grade forecasts herein has concentrated on toll traffic and revenues, the distinction along with its associated review and validation processes apply to the projected revenue for any funding source for which project investment decisions will be made or financing will be secured.

Regional Toll Revenue Considerations

For the Puget Sound region, more detailed market research regarding the behavioral nature and characteristics of potential road users, including their willingness to pay tolls, is needed to inform investment grade forecasts. Similarly, extensive travel demand modeling with better tools are required to apply the results of such research and better estimate toll elasticities of demand. It is likely that investment grade results would require a development of an independent and specialized travel demand forecasting model, or further refinement and modifications to the existing PSRC regional travel demand model, in order to provide adequate capabilities to conduct detailed sensitivity analysis of various pricing and travel benefit combinations. Development of such a tool would require a variety of professionals with specialized skills and experience in which the following activities would likely be undertaken.

- **Detailed market research, most likely including a stated-preference survey (SPS) —** Market research would need to be conducted to identify and gauge travel market behavior, willingness to pay by trip purpose, frequency, and income range, preferences regarding time and travel benefit trade-offs, and socio-economic aspects. If an existing toll facility with similar characteristics to the proposed facility serves the same or similar markets, then it may be possible to use revealed preference and/or panel survey data of the existing toll facility user market to identify likely behavior for the proposed facility. However, since there are no other comparable toll facilities operating in the Puget Sound Region to allow for this, it is essential that some SPS research be undertaken. The resulting survey information is required to provide pertinent quantitative data on potential toll users' sensitivity with respect to willingness-to-pay, socio-economic characteristics, and other travel behavior attributes. SPS data may need to be pooled with other travel survey data already collected by PSRC.

- **Develop a toll mode choice model —** A toll mode choice model would need to be developed to allow more accurate simulation of travel behavior decisions with respect to pricing trade-offs in the travel forecasting process. This task will also involve using appropriate statistical techniques to estimate toll elasticities of demand for various market segments. Such a toll mode choice model has been recently developed for facilities in Houston and Orlando.
- **Integrate the toll mode choice model with the applicable travel demand model —** The toll mode choice model would then be implemented within either a newly developed travel demand forecasting model or a modified and refined PSRC model. This task may involve reliance on experience from toll operations in other regions across the country (e.g., Houston, Orlando, San Diego, etc.)

- **Model and estimate toll revenues and/or toll pricing structures —** Upon fully completing data collection and model development, toll revenue forecasts would be prepared and/or toll pricing structures would be estimated according to desired facility and network operating objectives (e.g., revenue maximization, economically efficient toll, throughput targets, etc.)
- **Independent Review and Documentation** — A panel of independent experts would be assembled to review and comment on the modeling process and forecast results, which may result in further refinements and process iteration to refine the estimates. A technical report would then be prepared to document above efforts, methodology and results in such a manner as to convey the level of conservatism and risks in the results and inform experts in the finance industry.

A key product of this process would be reliable estimates for the toll elasticity of demand over a range of toll rates, trip purposes, and user demographics. This would facilitate the development of an optimum pricing structure to serve the real world operating objective(s), as well as allow for sensitivity analyses testing of different pricing schemes.

Revenue Maximization versus Maximum Societal Benefits

Earlier in this report, several toll road operating objectives were presented and discussed. As roadway pricing receives additional attention and consideration as a source of funding and congestion management tool, policy-makers will need to deliberate the relative merits of these objectives. The primary debate centers upon whether or not tolls should be set to maximize revenue or at some lower level with the intent of maximizing the efficiency of the entire network by minimizing overall network travel time, or even potentially lower to maximize throughput on the individual facility. At first glance, the middle objective would appear to maximize societal travel benefits subject to the constraints imposed. Similarly, the former may cause a higher, sub-optimal level of diversion to arterial roads that increases overall system delay by transferring more delay to the un-priced roads than it provides in time savings for toll road users. And the latter could potentially over utilize the freeway system from an overall network efficiency standpoint. However, the issue is not quite as simple as it seems, since it depends on the linkage between the toll revenues and infrastructure investments. In other words, if one assumes that the level of investment is a function of the toll revenues, and that a higher level of investment provides additional travel benefits, then a detailed benefit-cost analysis may be needed to help understand the ramifications of various tolling objectives.

The investment grade traffic and toll revenue tools would also serve to help inform the toll road operating objective/toll policy debate.

KEY FINDINGS

- Travel levels on the highway network of King and South Snohomish Counties have reached critical levels relative to available capacity to make value pricing of this capacity a viable method to manage demand to prevent congestion and generate new revenue to fund transportation improvements.
  - Seven major highways in King and South Snohomish County totaling 131 miles were modeled as toll facilities for this study. This regional toll network differs from that included in Regional Transportation Improvement District (RTID) proposed by the County Executives of King, Snohomish, and Pierce Counties. Additional context information about the County Executives' proposal is included in the main report.
- Simulating tolls in the regional travel demand model for seven major highway facilities yields optimal toll rates that seek to *minimize overall network travel time* with the objective of economic efficiency. These toll rates are higher than those which would *maximize facility throughput* but lower than those which would *maximize toll revenue*.
  - The maximum throughput objective may sound appealing, but would likely be sub-optimal not only from a revenue standpoint, but also because it would spend more of the public's time at a higher total social cost to get the maximum number vehicles through than would result with a higher toll rate.
  - There may be cause to set tolls closer to revenue maximizing levels if other tolling objectives do not generate sufficient revenue to support the improvement expenditures.
- In the assumed year of implementation (2014), these toll rates range from 4¢ to 42¢ per mile in year of collection dollars, depending on the location, time of day and travel direction.
  - Peak period toll rates would typically average around 11¢ per mile, whereas off-peak toll rates would hover about 4¢ per mile.
  - The optimal toll rates will need to increase periodically due to both inflation and growing travel demand, if the roadway is to be managed to maintain optimal network results and avoid congested conditions. These toll increases will require that the operating objectives and management policies of the facility be well established and clearly communicated to the public and policy-makers. It may be useful to craft toll enabling legislation to allow the toll authority to set toll rates at the minimum levels designed to maintain a certain speed threshold.
- At the time of writing, general tolling of federally funded interstate highways is highly restricted. Implementation of any regional tolling concept would likely require that these restrictions be relaxed. There is some indication that this may occur in the next federal transportation funding authorization act.
- For 2014, the projected toll revenue is estimated to range from approximately $252 to $457 million per year in inflated dollars, depending on the underlying value of time assumption and various operating parameters, and before operating and maintenance expenses. This estimated annual range is expected to grow to between $535 and $955 million by 2030 assuming tolls escalate with demand growth and inflation.

- The top end of this range applies the base value of time ($11.83 per hour), includes weekend tolling, and tolls trucks at an average rate of three times the auto toll, but does not represent the revenue maximizing situation. The assumptions underlying the top end of this range are not overly optimistic.
- The bottom end of this range applies the low value of time ($7.89 per hour), excludes tolls on weekends, and toll trucks at an average rate of two times the auto toll. The assumptions underlying the bottom end of this range are fairly conservative.

■ Implementation of tolls will cause travel demand on these facilities to decrease as those users whose cost of travel in time plus tolls exceeds the benefits from travel seek other options.

- Some users will divert to other un-priced alternative routes, lower cost times of travel, closer destinations or lower cost modes (HOVs and transit). Others will eliminate their trips altogether or combine trips.
- The model results may over-estimate the true diversion away from the toll facilities, which would tend to understate the optimal toll rates and toll revenue potential. Further research and model refinements would be needed to better understand diversion impacts, especially to the arterial street system.

■ Assuming toll revenues were immediately available to begin debt service payments (not particularly relevant in this case of multiple projects of long construction duration), each $1 million of annual toll revenue, net of any operating costs, could leverage approximately $9-11 million of capital investment via the sale of municipal revenue bonds or similar debt instruments.

- It may not be realistic to assume that toll revenues would be immediately available to service debt. However, a more realistic assessment of toll revenue financial capacity would require detailed information regarding the timing of other revenue sources, proposed debt instruments, construction costs and phasing, toll collection implementation and technologies, and a host of other factors (e.g., debt service coverage requirements, issuance costs, debt terms and duration, etc.) which would serve as input to a detailed financial analysis of regional highway investments.

■ Additional policy and institution factors that need further consideration:

- Potential diversion impacts to the arterial street network needs further study, including a detailed analysis of how diversion impacts arterials and consideration of local jurisdiction concerns and priorities.
- Policy and legal issues regarding the tolling of existing facilities, be they interstate highways funded with federal dollars or facilities that do not receive improvements, need to be considered in the context of the interdependence of a regional toll network.
- Further study of the technological and economic feasibility of implementing wide-spread electronic toll collection, including capital investment costs and ongoing operating, maintenance and administrative expenses, needs to be undertaken.
- A detailed financial analysis is needed to gauge the appropriate capacity of the projected revenue stream for financing the system of proposed projects and related improvements.

SOURCES CONSULTED

Dehghani, Youssef and William Olsen. *Potential Pitfalls in Forecasting Travel Demand for Toll Roads: Experience in the U.S. and Overseas.* Presented at the 78th Annual Meeting of the Transportaton Research Board, 1999.

Pozdena, Randall. *Transportation Pricing Alternatives Study – Technical Memorandum 3: Simulating Congestion Pricing in EMME/2*, prepared for the Puget Sound Regional Council. ECONorthwest, 2000.

Small, Kenneth A. *NCHRP Report 431: Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation*. Transportation Research Board, National Academy Press, Washington D.C., 1999.

Small, Kenneth A. *Urban Transportation Economics*. Harwood Academic Publishers, Chur, Switzerland, 1992.

Sullivan, Edward, et al. *Continuation Study to Evaluate the Impacts of the SR-91 Value-Priced Express Lanes – Final Report*, prepared for the State of California Department of Transportation. Cal Poly State University San Luis Obispo, 2000.

Supernak, Janusz, et al. *I-15 Congestion Pricing Project – Task 5 Phase II Year Three Cost of Delay Study*, prepared for the San Diego Association of Governments. San Diego State University, 2001.

Supernak, Janusz, et al. *I-15 Congestion Pricing Project – Task 5 Phase II Year Three Overall Report*, prepared for the San Diego Association of Governments. San Diego State University, 2001.

Transportation Research Board. *Highway Capacity Manual 2000.* National Research Council, Washington, D.C., 2000.

Waters, II, W. G. *Values of Travel Time Savings and the Link with Income*. Paper prepared for presentation at the Annual Meeting of the Canadian Transportation Research Forum, Banff, Alberta, 1992.

Washington State Employment Security Department. *Employment and Income by County – 2000.* Olympia, WA, 2001.

APPENDIX

Table A - 1
Toll Analysis Segments by Facility

Toll Facility & Analysis Segment	Segment Distance (miles)
SR-99	
Roy to Broad/Alaskan Wy	0.93
Broad/Alaskan Wy to Midtown ramps	1.09
Midtown ramps to 1st Ave ramps	0.57
1st Ave ramps to Spokane	2.34
Spokane to 1st Ave So	1.14
SR-509	
1st Ave So to SR 518	5.51
SR 518 to SR 99	4.41
SR 99 to I-5	1.83
I-5	
I-405 to 220th	3.35
220th to 175th	3.13
175th to Northgate	3.24
Northgate to Lake City*	2.30
Lake City to SR 520*	2.55
SR 520 to Mercer*	1.18
Mercer to Olive*	0.69
Olive to James*	0.86
James to I-90	0.70
I-90 to Michigan	3.30
Michigan to Pacific Hwy	3.29
Pacific Hwy to Southcenter	3.53
Southcenter to SR 516	5.31
SR 516 to 320th	5.32
320th to Pierce County border	4.32
** Includes I-5 Express Lanes*	
I-405	
I-5 to 124th	10.04
124th to SR 520	5.39
SR 520 to I-90	3.73
I-90 to Park	5.76
Park to SR 167	3.00
SR 167 to Southcenter	2.28
SR-167	
I-405 to 212th	3.88
212th to 15th	6.70
15th to Ellingston	3.48
I-90	
I-5 to Rainier	0.86
Rainier to 77th	3.60
77th to I-405	3.03
I-405 to SR 900	5.84
SR-520	
I-5 to Montlake ramps	1.57
Montlake ramps to 84th	2.95
84th to I-405	2.36
I-405 to NE 40th	3.21
NE 40th to SR 202	2.72

Table A - 2
Spectrum of Optimal Toll Rates for 2014 in 2000 Dollars
(Base Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.03	$0.16	$0.08	$0.03	$0.16	$0.08	$0.03	$0.03	$0.03
SR-509	11.8	$0.03	$0.10	$0.06	$0.03	$0.10	$0.06	$0.03	$0.03	$0.03
I-5	43.1	$0.03	$0.24	$0.10	$0.03	$0.15	$0.07	$0.03	$0.03	$0.03
I-405	30.2	$0.03	$0.14	$0.08	$0.03	$0.08	$0.05	$0.03	$0.03	$0.03
SR-167	14.1	$0.03	$0.14	$0.09	$0.03	$0.11	$0.06	$0.03	$0.03	$0.03
I-90	13.3	$0.03	$0.19	$0.09	$0.03	$0.13	$0.06	$0.03	$0.03	$0.03
SR-520	12.8	$0.04	$0.31	$0.14	$0.03	$0.21	$0.09	$0.03	$0.05	$0.03
Network	**131.3**	**$0.03**	**$0.31**	**$0.09**	**$0.03**	**$0.21**	**$0.07**	**$0.03**	**$0.05**	**$0.03**

Note: All amounts in year 2000 dollars

Table A - 3
Spectrum of Optimal Toll Rates for 2014 in 2000 Dollars
(Low Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.02	$0.11	$0.05	$0.02	$0.11	$0.05	$0.02	$0.02	$0.02
SR-509	11.8	$0.02	$0.07	$0.04	$0.02	$0.07	$0.04	$0.02	$0.02	$0.02
I-5	43.1	$0.02	$0.16	$0.07	$0.02	$0.10	$0.05	$0.02	$0.02	$0.02
I-405	30.2	$0.02	$0.09	$0.06	$0.02	$0.05	$0.03	$0.02	$0.02	$0.02
SR-167	14.1	$0.02	$0.10	$0.06	$0.02	$0.07	$0.04	$0.02	$0.02	$0.02
I-90	13.3	$0.02	$0.12	$0.06	$0.02	$0.09	$0.04	$0.02	$0.02	$0.02
SR-520	12.8	$0.03	$0.20	$0.09	$0.02	$0.14	$0.06	$0.02	$0.03	$0.02
Network	**131.3**	**$0.02**	**$0.20**	**$0.06**	**$0.02**	**$0.14**	**$0.04**	**$0.02**	**$0.03**	**$0.02**

Note: All amounts in year 2000 dollars

Table A - 4
Spectrum of Optimal Toll Rates for 2030 in Inflated Dollars
(Base Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.07	$0.36	$0.20	$0.07	$0.36	$0.20	$0.06	$0.07	$0.06
SR-509	11.8	$0.07	$0.23	$0.16	$0.07	$0.23	$0.16	$0.06	$0.06	$0.06
I-5	43.1	$0.09	$0.62	$0.27	$0.06	$0.40	$0.17	$0.06	$0.11	$0.07
I-405	30.2	$0.06	$0.43	$0.25	$0.06	$0.25	$0.14	$0.06	$0.09	$0.06
SR-167	14.1	$0.12	$0.36	$0.24	$0.06	$0.27	$0.15	$0.06	$0.06	$0.06
I-90	13.3	$0.06	$0.47	$0.27	$0.06	$0.27	$0.16	$0.06	$0.09	$0.07
SR-520	12.8	$0.13	$0.87	$0.40	$0.06	$0.44	$0.23	$0.06	$0.16	$0.09
Network	**131.3**	**$0.06**	**$0.87**	**$0.26**	**$0.06**	**$0.44**	**$0.17**	**$0.06**	**$0.16**	**$0.07**

Note: All amounts in year of collection dollars

Table A - 5
Spectrum of Optimal Toll Rates for 2030 in Inflated Dollars
(Low Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.04	$0.24	$0.14	$0.04	$0.24	$0.14	$0.04	$0.05	$0.04
SR-509	11.8	$0.04	$0.16	$0.11	$0.04	$0.16	$0.11	$0.04	$0.04	$0.04
I-5	43.1	$0.06	$0.41	$0.18	$0.04	$0.27	$0.11	$0.04	$0.07	$0.05
I-405	30.2	$0.04	$0.29	$0.16	$0.04	$0.17	$0.09	$0.04	$0.06	$0.04
SR-167	14.1	$0.08	$0.24	$0.16	$0.04	$0.18	$0.10	$0.04	$0.04	$0.04
I-90	13.3	$0.04	$0.31	$0.18	$0.04	$0.18	$0.11	$0.04	$0.06	$0.05
SR-520	12.8	$0.09	$0.58	$0.27	$0.04	$0.29	$0.15	$0.04	$0.11	$0.06
Network	**131.3**	**$0.04**	**$0.58**	**$0.18**	**$0.04**	**$0.29**	**$0.11**	**$0.04**	**$0.11**	**$0.04**

Note: All amounts in year of collection dollars

Table A - 6
Spectrum of Optimal Toll Rates for 2030 in 2000 Dollars
(Base Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.03	$0.17	$0.10	$0.03	$0.17	$0.09	$0.03	$0.03	$0.03
SR-509	11.8	$0.03	$0.11	$0.08	$0.03	$0.11	$0.08	$0.03	$0.03	$0.03
I-5	43.1	$0.04	$0.29	$0.13	$0.03	$0.19	$0.08	$0.03	$0.05	$0.03
I-405	30.2	$0.03	$0.20	$0.12	$0.03	$0.12	$0.07	$0.03	$0.04	$0.03
SR-167	14.1	$0.05	$0.17	$0.11	$0.03	$0.13	$0.07	$0.03	$0.03	$0.03
I-90	13.3	$0.03	$0.22	$0.13	$0.03	$0.13	$0.07	$0.03	$0.04	$0.03
SR-520	12.8	$0.06	$0.40	$0.19	$0.03	$0.21	$0.11	$0.03	$0.07	$0.04
Network	**131.3**	**$0.03**	**$0.40**	**$0.12**	**$0.03**	**$0.21**	**$0.08**	**$0.03**	**$0.07**	**$0.03**

Note: All amounts in year 2000 dollars

Table A - 7
Spectrum of Optimal Toll Rates for 2030 in 2000 Dollars
(Low Value of Time)

Toll Facility	Toll Distance	PM Peak Period — $ / mi			AM Peak Period — $ / mi			Off-Peak / Weekend — $ / mi		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
SR-99	6.1	$0.02	$0.11	$0.06	$0.02	$0.11	$0.06	$0.02	$0.02	$0.02
SR-509	11.8	$0.02	$0.07	$0.05	$0.02	$0.07	$0.05	$0.02	$0.02	$0.02
I-5	43.1	$0.03	$0.19	$0.09	$0.02	$0.12	$0.05	$0.02	$0.03	$0.02
I-405	30.2	$0.02	$0.13	$0.08	$0.02	$0.08	$0.04	$0.02	$0.03	$0.02
SR-167	14.1	$0.04	$0.11	$0.08	$0.02	$0.08	$0.05	$0.02	$0.02	$0.02
I-90	13.3	$0.02	$0.15	$0.09	$0.02	$0.08	$0.05	$0.02	$0.03	$0.02
SR-520	12.8	$0.04	$0.27	$0.12	$0.02	$0.14	$0.07	$0.02	$0.05	$0.03
Network	**131.3**	**$0.02**	**$0.27**	**$0.08**	**$0.02**	**$0.14**	**$0.05**	**$0.02**	**$0.05**	**$0.02**

Note: All amounts in year 2000 dollars

Table A - 8
Annual Revenue by Facility for Selected Years — <u>High End</u> Estimates
(Constant 2000 Dollars)

Toll Facility	*Toll Distance*	*Year 2000 Dollars in Millions*			
		2014	*2020*	*2025*	*2030*
SR-99	6.1	$10.8 M	$11.4 M	$12.0 M	$12.8 M
SR-509	11.8	$14.7 M	$15.6 M	$16.4 M	$17.3 M
I-5	43.1	$138.3 M	$151.9 M	$165.6 M	$181.0 M
I-405	30.2	$87.0 M	$98.2 M	$109.5 M	$122.4 M
SR-167	14.1	$23.7 M	$25.7 M	$27.6 M	$29.6 M
I-90	13.3	$30.6 M	$34.4 M	$38.2 M	$43.2 M
SR-520	12.8	$29.3 M	$32.8 M	$36.2 M	$40.4 M
Network	**131.3**	**$334.3 M**	**$370.1 M**	**$405.5 M**	**$446.7 M**

Table A - 9
Annual Revenue by Facility for Selected Years — <u>Low End</u> Estimates
(Constant 2000 Dollars)

Toll Facility	*Toll Distance*	*Year 2000 Dollars in Millions*			
		2014	*2020*	*2025*	*2030*
SR-99	6.1	$6.2 M	$6.6 M	$6.9 M	$7.4 M
SR-509	11.8	$8.4 M	$8.9 M	$9.4 M	$10.0 M
I-5	43.1	$75.2 M	$83.1 M	$90.9 M	$99.7 M
I-405	30.2	$47.1 M	$53.8 M	$60.5 M	$68.1 M
SR-167	14.1	$13.1 M	$14.3 M	$15.4 M	$16.6 M
I-90	13.3	$17.6 M	$19.9 M	$22.2 M	$25.2 M
SR-520	12.8	$16.8 M	$18.9 M	$20.9 M	$23.4 M
Network	**131.3**	**$184.3 M**	**$205.5 M**	**$226.3 M**	**$250.3 M**

Table A - 10
Annual Vehicle Miles Traveled by Facility (with Tolls)

Toll Facility	Toll Distance	Millions of Vehicle Miles Traveled					
		2006	2013	2014	2020	2025	2030
SR-99	6.1	187 M	192 M	192 M	196 M	200 M	204 M
SR-509	11.8	260 M	267 M	268 M	275 M	281 M	287 M
I-5	43.1	2,212 M	2,299 M	2,312 M	2,390 M	2,458 M	2,528 M
I-405	30.2	1,577 M	1,658 M	1,670 M	1,742 M	1,806 M	1,872 M
SR-167	14.1	354 M	366 M	368 M	379 M	389 M	398 M
I-90	13.3	448 M	471 M	474 M	495 M	513 M	532 M
SR-520	12.8	334 M	345 M	347 M	357 M	366 M	376 M
Network	**131.3**	**5,372 M**	**5,598 M**	**5,631 M**	**5,836 M**	**6,013 M**	**6,197 M**

Table A - 11
Overall Average Daily Toll Rates by Year in Inflated Dollars

Toll Facility	Toll Distance	Year 2000 Dollars in Millions			
		2014	2020	2025	2030
SR-99	6.1	$0.08 / mi	$0.10 / mi	$0.11 / mi	$0.13 / mi
SR-509	11.8	$0.07 / mi	$0.09 / mi	$0.11 / mi	$0.13 / mi
I-5	43.1	$0.08 / mi	$0.11 / mi	$0.13 / mi	$0.15 / mi
I-405	30.2	$0.07 / mi	$0.09 / mi	$0.11 / mi	$0.14 / mi
SR-167	14.1	$0.09 / mi	$0.11 / mi	$0.13 / mi	$0.16 / mi
I-90	13.3	$0.09 / mi	$0.12 / mi	$0.14 / mi	$0.17 / mi
SR-520	12.8	$0.12 / mi	$0.15 / mi	$0.19 / mi	$0.23 / mi
Network	**131.3**	**$0.08 / mi**	**$0.11 / mi**	**$0.13 / mi**	**$0.16 / mi**

Table A - 12
Overall Average Daily Toll Rates by Year in Constant 2000 Dollars

Toll Facility	Toll Distance	Year 2000 Dollars in Millions			
		2014	2020	2025	2030
SR-99	6.1	$0.06 / mi	$0.06 / mi	$0.06 / mi	$0.06 / mi
SR-509	11.8	$0.05 / mi	$0.06 / mi	$0.06 / mi	$0.06 / mi
I-5	43.1	$0.06 / mi	$0.06 / mi	$0.07 / mi	$0.07 / mi
I-405	30.2	$0.05 / mi	$0.06 / mi	$0.06 / mi	$0.07 / mi
SR-167	14.1	$0.06 / mi	$0.07 / mi	$0.07 / mi	$0.07 / mi
I-90	13.3	$0.06 / mi	$0.07 / mi	$0.07 / mi	$0.08 / mi
SR-520	12.8	$0.08 / mi	$0.09 / mi	$0.10 / mi	$0.11 / mi
Network	**131.3**	**$0.06 / mi**	**$0.06 / mi**	**$0.07 / mi**	**$0.07 / mi**

Table A - 13
Historical and Projected Inflation
(Implicit Price Deflator for Personal Consumption)

Year	*Annualized Implicit Price Deflator Index*	*Annual Growth Factor*	*Annual Escalation Factor for Year 2000*
1996	1.0002		
1997	1.0195	1.0193	
1998	1.0302	1.0105	
1999	1.0472	1.0165	
2000	1.0750	1.0265	1.0000
2001	1.0952	1.0189	1.0189
2002	1.1057	1.0096	1.0286
2003	1.1297	1.0217	1.0509
2004	1.1555	1.0228	1.0749
2005	1.1815	1.0225	1.0991
2006	1.2072	1.0218	1.1230
2007	1.2345	1.0226	1.1484
2008	1.2620	1.0223	1.1740
2009	1.2905	1.0226	1.2005
2010	1.3202	1.0231	1.2281
2011	1.3530	1.0248	1.2586
2012	1.3902	1.0275	1.2932
2013	1.4300	1.0286	1.3302
2014	1.4705	1.0283	1.3679
2015	1.5127	1.0287	1.4072
2016	1.5569	1.0292	1.4484
2017	1.6047	1.0307	1.4928
2018	1.6582	1.0333	1.5425
2019	1.7167	1.0353	1.5969
2020	1.7819	1.0380	1.6576
2021	1.8253	1.0244	1.6980
2022	1.8701	1.0246	1.7397
2023	1.9172	1.0252	1.7834
2024	1.9661	1.0255	1.8290
2025	2.0162	1.0255	1.8755
2026	2.0681	1.0258	1.9238
2027	2.1228	1.0264	1.9747
2028	2.1793	1.0266	2.0273
2029	2.2377	1.0268	2.0816
2030	2.2980	1.0270	2.1377